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CONTENTS

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THE NUTRITIONAL VALUE OF RAPESEED OIL MEAL FOR LAMB AND WOOL PRODUCTION IN MATURE RANGE EWES[1]

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[Received for publication May 11, 1960]

ABSTRACT

During a 2-year period mature range ewes were fed rations containing 10, 20, and 30 per cent rapeseed oil meal. These rations were compared with a control ration, to 10 and 20 per cent linseed oil meal rations, and to one consisting entirely of alfalfa hay.

Data were collected on body weight of ewes and lambs, weight of clean wool produced, length of wool fibre, and diameter of the fibre.

In the majority of criteria that were used to assess the value of these rations, the control, alfalfa hay, and 30 per cent rapeseed oil meal rations were inferior to the 10 and 20 per cent linseed oil meal and the 10 and 20 per cent rapeseed oil meal rations.

Because the 30 per cent rapeseed meal ration lacked palatability, the average daily feed intake was lowest in this group. The ewes receiving this ration lost weight during pregnancy, their lambs were lighter ($P < .05$) at birth and at 6 weeks of age, and their wool production was less than any of the other groups.

No enlarged thyroids were observed in any of the ewes as a result of feeding rapeseed oil meal.

INTRODUCTION

In recent years the production of rapeseed oil meal (ROM) has become of commercial significance in Western Canada. It is comparable to linseed oil meal (LOM) in chemical composition and, although it is not highly palatable and contains a goitrogenic and growth depressing factor, it is used as a protein supplement for livestock.

An excellent review of the nutritional value of ROM has been published by Bell (1). He reported that Clandinin found Argentine-type ROM to be more toxic for chicks than the Polish type. At least two toxic compounds have been found in rapeseed oil meal, namely thiooxazolidone and isothiocyanates (and isothiocyanate precursors).

Digestibility data with sheep and cattle have revealed consistently lower digestion coefficients for organic matter in ROM when compared with LOM. Work from this Station (6) with lambs and from the University of Saskatchewan (2) with ewes has indicated that ROM is a satisfactory feed for this class of stock but that palatability may be a problem. Bell (1) concluded that ruminants are less susceptible than other classes of livestock, to the effects of the toxic factors in ROM. In swine (1), rats (7), and chicks (5) decreased rates of gain were noted as the percentage of ROM in the ration was increased.

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TABLE 1. — PERCENTAGE COMPOSITION AND CHEMICAL ANALYSIS OF RATIONS

	Experiment 1						Experiment 2			
	1	2	3	4	5	6	1	2	3	4
	Control	10% LOM	20% LOM	10% ROM	20% ROM	Alfalfa	10% LOM	10% ROM	20% ROM	30% ROM
Composition of rations	%	%	%	%	%	%	%	%	%	%
Alfalfa hay	—	—	—	—	—	100	—	—	—	—
Grass hay	50	50	50	50	50	—	50	50	50	50
Oat hulls	15	15	15	15	15	—	15	15	15	14
Beet molasses	5	5	5	5	5	—	5	5	5	5
Minerals and vitamins	1	1	1	1	1	—	1	1	1	1
Wheat (ground)	29	19	9	19	9	—	19	19	9	—
Linseed meal	—	10	20	—	—	—	10	—	—	—
Rapeseed meal	—	—	—	10	20	—	—	10	20	30
Chemical analysis										
Dry matter	91.4	91.5	91.2	90.8	91.0	90.6	90.6	90.8	91.0	90.7
Protein	6.1	9.1	11.7	9.1	11.9	10.9	10.6	10.8	12.7	15.4
Ether extract	1.5	1.6	2.0	2.0	2.6	1.4	1.9	2.0	2.4	3.3
Crude fibre	21.0	21.4	22.3	22.3	23.6	34.6	22.2	22.2	23.0	23.1
Ash	5.9	6.2	6.7	6.4	6.8	7.2	6.2	6.4	6.8	6.8
Gross energy (Therms/lb.)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Reports on the relative effect of these goitrogenic compounds on male and female animals are contradictory. Bell (1) found female mice better able than male mice to tolerate the toxic effects of ROM, while Hussar and Bowland (4) reported that female rats were more susceptible than males to the goitrogen and growth-depressing factors. Ovariectomy of female rats appeared to reduce this susceptibility. In order to assess its value for wool growth and lamb production in pregnant and lactating ewes, two feeding trials were conducted; one during the breeding season of 1957-58 and the other during 1958-59.

PROCEDURE

Experiment 1

Ninety-six mature grade ewes were divided into six lots, uniform with respect to body weight, and fed from September 10, 1957, to June 16, 1958. Rams were with the ewes from November 15 to December 15, giving lambing dates from approximately April 15 to May 15. They were housed in an open shed and were fed individually, twice a day, the rations shown in Table 1. The experiment was designed to compare 10 and 20 per cent ROM rations with 10 and 20 per cent LOM rations and, also, with a basal ration and one made up of alfalfa hay only. The ROM was expeller processed and was a mixture of Argentine and Polish varieties. It contained 2.09 milligrams of isothiocyanates and 2.41 milligrams of thiooxazolidone per gram of meal. Groups 1 to 5 inclusive received 3 pounds of the rations per ewe per day while Group 6 received 3½ pounds of the alfalfa hay in order that the digestible energy intake of all groups would be about equal. In all groups the hay was fed in the chopped form while the concentrate was fed in pellet form. Water was before the animals at all times, except when they were in the feeding stalls. Lambs were creep-fed whole oats starting at 2 weeks of age.

The proximate chemical composition of the rations is shown in Table 1. Digestibility trials were carried out on all rations with 4 sheep on each ration. This involved a 10-day preliminary period and a 10-day collection period. Feces were dried each day and the urine was preserved in a refrigerator, 1 millilitre of 10 per cent sulphuric acid having been added to the collection bottle each day.

A 2 x 2-cm. area was tattooed on the right shoulder of each ewe at the start of the experiment. Total weight of clean wool, total fibre length, and average fibre diameter were measured on this area for the period of the trial.

Ewes were weighed at 28-day intervals during the experiment and within 12 hours after lambing. The lambs were weighed at birth and weekly thereafter to 6 weeks of age.

Duncan's multiple range test (3) was used as a test for significant differences between treatments.

At the completion of the experiment, 4 ewes from the 20 per cent LOM ration and 4 from the 20 per cent ROM ration were killed and their thyroids examined.

TABLE 2. — AVERAGE FEED CONSUMPTION, WEIGHT OF EWES AND LAMBS, AND WOOL PRODUCTION

	Experiment 1						Experiment 2			
	1	2	3	4	5	6	1	2	3	4
	Control	10% LOM	20% LOM	10% ROM	20% ROM	Alfalfa	10% LOM	10% ROM	20% ROM	30% ROM
Average daily feed intake (lb.)	3.0	3.0	3.0	3.0	3.0	3.5	2.8	2.8	2.8	2.5
Average daily digestible crude protein (DCP) intake (lb.)	0.09	0.18	0.26	0.18	0.24	0.23	0.19	0.20	0.23	0.27
Average protein retained (D.C.P. less urine protein) (lb.)	0.05	0.09	0.09	0.09	0.05	0.08	0.09	0.10	0.05	0.07
Average daily dig. energy intake (Therms)	3.2	3.8	3.6	3.8	3.4	3.8	3.5	3.5	3.1	3.3
Average daily energy utilized (dig. energy less urine energy) (Therms)	3.1	3.7	3.4	3.7	3.2	3.6	3.4	3.4	2.9	2.8
No. of ewes per lot	16	16	16	16	16	16	16	16	16	16
No. of ewes that lambed	15	16	14	15	15	15	14	15	15	14
No. of lambs born	22	19	19	19	19	19	18	21	23	18
Average weight of lambs at birth (lb.)[1]	10.9	11.4	11.6	10.8	10.6	10.4	11.0	10.7	10.6	9.7
Average weight of lambs at 6 weeks (lb.)[1]	29.9	34.3	32.3	30.6	30.5	32.6	34.6	33.4	31.4	28.5
Average initial weight of ewes (lb.)	114	117	116	115	114	117	128	126	126	126
Average weight of ewes after lambing (lb.)	125	150	146	136	133	132	131	132	133	122
Average weight of clean wool (mg.)[2]	359	476	518	399	435	418	340	393	415	313
Average fibre length (mm.)	63	66	71	65	68	68	63	67	69	61
Average fibre thickness (μ)	20	22	23	22	21	21	21	22	22	21

[1]Adjusted to weight of single male
[2]From 2 x 2 cm.-area adjusted to 200 days of growth

Experiment 2

On December 16, 1958, 64 grade ewes similar to those in Experiment 1 were divided into four groups, placed on the rations shown in Table 1 and kept on these rations until June 9, 1959. This experiment was designed to repeat some of the previous year's work and to note the effect of increasing the rapeseed meal content of the ration to 30 per cent. The ewes and lambs were handled, fed, and housed in a similar manner to those in the first experiment. The proximate chemical composition of the rations is presented in Table 1. The same data were collected as in Experiment 1 and they were subjected to the same statistical analysis.

RESULTS AND DISCUSSION

Data on sheep, lambs, wool production, and feed consumption are presented in Table 2. Birth weights and 6-week weights of single female lambs, twin male lambs, and twin female lambs were adjusted to single male weights by adding the following amounts:

	Birth weight	6-week weight
Single female	0.5 lb.	0.4 lb.
Twin male	2.5 lb.	10.0 lb.
Twin female	3.0 lb.	9.0 lb.

These adjustments were based on 10 years' lambing data at Lethbridge from ewes similar to those used in these experiments.

In Experiment 1 the quantities of protein retained from the 10 and 20 per cent LOM rations and the 10 per cent ROM ration were equal. However, when the content of ROM was increased to 20 per cent, the amount of protein retained decreased to a level equal to that of the control ration. Alfalfa hay compared favourably with the LOM rations.

Although it was intended to feed all groups in Experiment 2 at the same level, the 30 per cent ROM ration lacked palatability and was consumed at a lower rate. The results shown in Table 2 indicate that the nutritive value of a ration containing 10 per cent ROM was equal to one containing 10 per cent LOM. However, as the per cent of ROM increased, the per cent of protein and energy retained decreased.

The ewes in both experiments gained weight during pregnancy except those on the 30 per cent ROM. Except for the 30 per cent ROM group there were no significant differences between groups in lambing weights of ewes.

In Experiment 1 the average birth weight of the lambs in the 20 per cent LOM group was higher ($P < .05$) than that of the alfalfa group but not significantly different from those in the other groups. At 6 weeks of age the lambs in the 10 per cent LOM group were heavier ($P < .05$) than those in the control and the 10 and 20 per cent ROM groups, but not heavier than those in the 20 per cent LOM or alfalfa groups.

In Experiment 2 the average lamb birth weights and the 6-week weights of the 10 per cent LOM and 10 per cent ROM groups were heavier

($P < .05$) than the lambs in the 30 per cent ROM group. The birth weights and 6-week weights of the lambs in the 20 per cent ROM group were intermediate and not significantly different from any of the other three groups.

The average weight of clean wool from the 2 x 2-cm. area in Experiment 1 was greater ($P < .05$) in the 20 per cent LOM group than in the control, the 10 per cent ROM, or the alfalfa group. The 10 per cent LOM also produced a greater weight of wool ($P < .05$) than the control ration but not significantly more than the other four groups. There were no significant differences between groups in the length of fibre produced. Fibre of a smaller ($P < .05$) diameter was produced by the control group than by the 10 per cent or 20 per cent LOM or the 10 per cent ROM groups but not significantly smaller than the 20 per cent ROM or alfalfa groups.

In Experiment 2 more clean wool ($P < .05$) and longer fibre ($P < .01$) were produced by the 20 per cent ROM group than by the 10 per cent LOM or the 30 per cent ROM groups. The 10 per cent ROM group produced more clean wool ($P < .05$) and longer fibre ($P < .05$) than the 30 per cent ROM group. The difference in weight of clean wool between the 20 per cent ROM and the 10 per cent ROM groups was not significant nor was the difference between the 10 per cent LOM and the 30 per cent ROM groups. There was no significant difference in fibre thickness between groups.

The data indicate that the 20 per cent LOM ration was superior to the other rations fed in the two experiments, followed closely by the 10 per cent LOM ration. This confirms previous work at this Station (7, 9, 10) which showed no significant difference in birth weights of lambs when the ewes are fed a 9.0 per cent protein ration (0.18 pound DCP intake per day) or a 12.0 per cent protein ration (0.26 pound DCP intake per day). Apparently 20 per cent ROM in a ration approaches maximum quantity allowable for good nutrition. In this experiment the 30 per cent ROM had definite deleterious effects on lamb and wool production. The ewes killed in the first experiment for thyroid examination showed no effects of the goitrogenic factor in ROM, nor did any of the ewes on the 30 per cent ration exhibit any visible evidence of enlarged thyroids. This confirms the opinion of Bell (1) that ruminants are less susceptible to the goitrogenic factor than other classes of stock.

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THE VALUE OF POTATOES FOR FEEDING DAIRY COWS[1]

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ABSTRACT

Twenty Ayrshire and twenty Holstein-Friesian cows were used at the Experimental Farms, Charlottetown, Prince Edward Island, and Fredericton, New Brunswick, respectively, in an evaluation of the use of raw potatoes for feeding lactating dairy cows. The experiments were of the change-over design and were conducted in the period 1956-59. It was concluded that potatoes were equal to grass silage on a T.D.N. basis, provided that the protein content of the grain mixture fed with the potatoes was also increased. Better T.D.N. consumption was obtained when both silage and potatoes were fed than when silage was fed alone. Increasing the protein content of the grain mixture fed with potatoes resulted in increased production of F.C.M. and S.N.F., but not of butterfat.

INTRODUCTION

Every year a substantial quantity of the potato crop is unsuitable for human food or for seed. In addition, during certain years surplus potatoes are produced. The development of economic outlets for low-grade and surplus potatoes is of vital importance to the potato industry. One such outlet is as feed for livestock. Information is required on the value of potatoes in feeding livestock and to determine the most efficient combination of feeds when using potatoes as part of the ration.

Allender (1) has reviewed work on the use of potatoes for feeding cattle in the United States. He presented data on the comparative feed value of fresh potatoes in terms of shelled corn, alfalfa hay, corn silage and mixed grain but did not refer to any comparisons with grass silage. Results of a previous trial at Charlottetown (5) showed that potatoes fed to dairy cows at the rate of 1¾ pounds per 100 pounds of body weight were nearly equivalent to turnips fed at the rate of 4 pounds per 100 pounds of weight. A similar trial at Fredericton (7) indicated that 1 pound of potatoes would replace 2 pounds of mangels in a ration for dairy cows.

The dry matter content of potatoes is approximately twice that of swedes and similar roots. Potatoes are practically free of fibre, and may be considered to be a watery concentrate rather than a succulent roughage. Data on digestibility of potatoes and of various potato products have been summarized by Woodward *et al.* (8).

There are no reports in the literature on comparative value of potatoes and grass silage as a source of succulence in rations for dairy cows. Since grass silage and potatoes differ in chemical composition of dry matter, it is important to determine whether they should be fed interchangeably or together. Results published by Dodsworth *et al.* (3) suggest that complementary effects might be encountered.

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MATERIALS AND METHODS

A double changeover design outlined by Cochran *et al.* (2) was used. Groups consisted of 4 cows each and all cows received each ration for a 28-day experimental period in a 4 x 4 latin square design. Changeover periods of 1 week were allowed before each experimental period. Experiments were conducted with Ayrshire cows at Charlottetown, P.E.I., using 16 cows (four groups) in the winter of 1956-57 and 4 cows (one group) in 1957-58. Similar experiments were conducted at Fredericton, N.B., with Holstein-Friesian cows. Twelve cows (three groups) were used at Fredericton during the 1956-57 winter and one group each of the 2 following years.

The rations used were as follows:

Ration A — Hay, grass silage, standard grain mixture
Ration B — Hay, grass silage, potatoes, standard grain mixture
Ration C — Hay, potatoes, standard grain mixture
Ration D — Hay, potatoes, high-protein grain mixture

Grain was fed at the rate of 1 pound per 6 pounds of 4 per cent fat-corrected milk (F.C.M.) based on the average production during the 10 days prior to the beginning of the experiment. The daily allowance of grain was reduced by 0.2 pound each week throughout the experiment. This was done to compensate for the normal decline in milk production and to avoid bias due to ration effects. The standard grain mixture consisted of: *Oats* 500, *barley* 200, *wheat bran* 200, *linseed oilmeal* 100 pounds. The high-protein grain mixture was composed of: *Oats* 350, *barley* 150, *wheat bran* 200, *linseed oilmeal* 300 pounds. Both mixtures were supplemented with 1 per cent of cobalt-iodized-salt and 2 per cent steamed bonemeal.

At the beginning of the experiment, hay was fed *ad libitum* with silage at the ratio of 1:3 until the level of consumption was determined. This level of feeding was used throughout the experiment, unless feed refusals became excessive. When this occurred, the total amount of feed offered was reduced, but the ratio of hay to silage was kept constant. Potatoes were pulped before feeding and fed at a rate which would provide the same amount of dry matter as would be provided by silage. On ration *B*, half the dry matter of the succulent portion of the roughage was provided by potatoes and half by silage.

Hay and grain were sampled daily and potatoes and silage were sampled weekly. Samples were composited for each experimental period. The dry matter content of each sample of potatoes and silage was determined at each station by drying to constant weight in electric ovens at 100°C. Proximate analyses of the composited samples were determined by the Analytical Chemistry Unit at Ottawa.

Milk production was recorded to the nearest 0.5 pound at each milking. Samples were taken from morning and evening milkings twice during each experimental period to determine butterfat and solids-not-fat (S.N.F.) content. Butterfat was determined by the standard Babcock method and S.N.F. was determined by the lactometer method.

The cows were weighed on 2 consecutive days at the beginning and end of each experimental period. Weighing was done at the same time each

TABLE I. — CHEMICAL ANALYSES OF FEEDS — AVERAGE FOR EACH YEAR

		Dry matter per cent			Crude protein per cent (dry matter basis)			Crude fibre per cent (dry matter basis)		
		1956-57	1957-58	1958-59	1956-57	1957-58	1958-59	1956-57	1957-58	1958-59
High protein grain mixture	Charlottetown	89.3	88.0	—	19.4	20.4	—	11.6	10.6	—
	Fredericton	90.0	89.9	88.4	20.9	22.9	23.6	10.5	10.8	10.6
Standard grain mixture	Charlottetown	88.8	87.5	—	15.0	15.1	—	11.8	10.8	—
	Fredericton	90.0	89.4	88.4	16.2	17.3	16.7	10.4	11.5	10.3
Potatoes	Charlottetown	22.6	20.9	—	10.2	10.6	—	2.3	2.2	—
	Fredericton	19.7	19.5	21.0	10.8	11.2	9.2	2.3	2.7	2.6
Silage	Charlottetown	23.3	25.4	—	12.9	12.4	—	32.1	31.0	—
	Fredericton	21.8	24.9	21.8	10.1	12.0	13.7	36.1	36.0	32.9
Hay	Charlottetown	90.4	88.3	—	10.1	7.4	—	35.5	32.1	—
	Fredericton	88.7	89.8	87.6	7.5	7.8	7.6	38.4	37.3	33.6

morning following milking and feeding of hay, but before feeding the succulent portion of the rations.

Wood shavings were used for bedding. Water was available in automatic water bowls at all times. The cows were turned into a dry lot for a short period for exercise when weather permitted.

Chemical analyses of feeds used in the experiment are presented in Table 1. Grass-legume field cured hay was used at both locations. The hay at Fredericton was harvested between the full- and late-bloom stages; hay at Charlottetown was harvested somewhat earlier. This is reflected in the average chemical analysis presented in Table 1. The silage used was mixed grass and legume with grasses predominating, except that in 1959 at Fredericton the silage was chiefly red clover. Sodium metabisulphite was used as a preservative at both stations in 1957 and at Fredericton in 1958. The potatoes were ungraded (field run) or sound culls removed during grading.

RESULTS AND DISCUSSION

Average data on feed consumption and milk production for each farm and for combined farms are presented in Table 2. In some years only one replicate of the experiment was fed at a farm. This meant that it was impractical to separate year differences from group differences in the statistical analyses* of the data. Four missing values in the Charlottetown data and six in the Fredericton data were estimated by the method of Snedecor (6).

No statistically significant differences in average production between the rations were found at Charlottetown. However, as shown in Table 2, ration *A* proved to be inferior to the others at Fredericton. This was at least partly due to the reluctance of the animals to consume the grass silage offered. The silage was cut during the last week of June each year at Fredericton when legumes were in the early bloom stage. Ensiled without wilting it was lower in dry matter and higher in crude fibre than that used at Charlottetown. Silage at Charlottetown was harvested at a slightly earlier stage of maturity and wilted somewhat before storage. Both groups of cows had received grass silage in years previous to the experiment.

At both locations the higher protein in ration *D* resulted in an improvement in production compared to ration *C*. This difference was statistically significant for the combined data at the $P = 0.05$ level for 4 per cent F.C.M. production and at the $P = 0.01$ level for S.N.F. production. Logan *et al.* (4) report that increasing the protein level above normal does not increase the S.N.F. content of the milk. They cite work indicating that feeds containing either 60 per cent of normal protein, or 75 per cent of normal energy, significantly lower S.N.F. content. This suggests that ration *C* was deficient in protein. As indicated in Table 2, T.D.N. consumption was very similar on the two rations.

The highest average butterfat test was obtained when ration *C* was fed. This was significantly higher ($P = 0.01$) only in comparison with

*Detailed statistical procedure was provided by P. Robinson, Statistical Research and Services, Canada Department of Agriculture, Ottawa.

TABLE 2. — AVERAGE PRODUCTION AND FEED CONSUMPTION PER COW PER 28-DAY EXPERIMENTAL PERIOD

		Location	Rations				Significance of difference
			A Grass silage	B Potatoes and silage	C Potatoes	D Potatoes High-protein grain mixture	
4% F.C.M. produced	lb.	Charlottetown	764	771	745	763	N.S.
		Fredericton	691	805	794	824	B, C, D>A**
		Average	728	788	770	794	B, C, D>A**; D>C*
Butterfat produced	lb.	Charlottetown	31.5	32.0	31.0	31.6	N.S.
		Fredericton	26.2	31.1	31.2	32.1	B, C, D>A**
		Average	28.8	31.6	31.1	31.8	B, C, D>A**
Butterfat test	per cent	Charlottetown	4.3	4.4	4.5	4.4	N.S.
		Fredericton	3.6	3.8	3.9	3.8	N.S.
		Average	4.0	4.1	4.2	4.1	C>A**
S.N.F. produced	lb.	Charlottetown	53.2	54.7	52.1	53.8	N.S.
		Fredericton	62.4	72.4	70.0	74.5	B, C, D>A**; D>C**
		Average	57.8	63.6	61.0	64.2	B, D>A**, C**; C>A**
Change in body weight	lb.	Charlottetown	−30	−14	−12	−1	B>A*; D>B*; C, D>A**
		Fredericton	−6	−6	+5	+2	N.S.
		Average	−18	−10	−4	0	C, D>A**; D>B*
T.D.N. consumed	lb.	Charlottetown	432	465	483	491	C, D>A, B**; B>A**
		Fredericton	475	558	593	597	C, D>A, B**; B>A**
		Average	454	512	538	544	C, D>A, B**; B>A**
Dry matter consumed	lb.	Charlottetown	698	707	695	705	N.S.
		Fredericton	776	864	881	868	B, C, D>A**
		Average	737	786	788	786	B, C, D>A**
Total feed consumed	lb.	Charlottetown	1534	1605	1589	1617	D, B>A**; C>A*
		Fredericton	1835	2155	2254	2268	B, C, D>A**; D>B**
		Average	1684	1880	1922	1942	B, C, D>A**; D>B*

**P<0.01, *P<0.05, N.S. = Non-significant

ration *A*. Although ration *C* was lower in milk production, there were no statistically significant differences between rations *B*, *C* and *D* in butterfat production.

The experiment was designed to give equal dry matter consumption on all rations. This was the case at Charlottetown, but at Fredericton dry matter consumption decreased when the animals were fed rations containing grass silage. Since it was planned to feed equal amounts of dry matter, it was expected that the total weight of feed and T.D.N. consumed would be higher for animals fed rations containing potatoes.

There were rather large differences among the rations in terms of T.D.N. consumed per 100 pounds of F.C.M. produced. However, when the average figures for T.D.N. consumption are corrected for body weight loss (assuming 1 pound of weight loss equals 2.73 pounds of ingested T.D.N.*) these differences are largely eliminated, being 68.8, 68.4, 71.3, and 68.5 pounds of T.D.N. required per 100 pounds of F.C.M. for rations *A*, *B*, *C* and *D* respectively. The differences between ration *C* and the other rations approached significance at the $P = 0.05$ level. This lower efficiency of conversion may be attributed to the wider protein to energy ratio of ration *C*.

Cows fed potatoes with the high-protein grain ration maintained their weight but those receiving silage lost an average of 0.64 pounds per day. At Charlottetown there were no differences in milk production between treatments but the weight loss on the silage ration (ration *A*) was considerably larger than on the others. Because the experiments were designed to ensure maximum consumption of hay and silage in the ratio of 1:3 it is apparent that a higher T.D.N. consumption can be attained when potatoes replace all or part of the silage in the ration. This difference was not sufficient to adversely affect milk production during the short experimental periods of these trials when the silage was of high quality (Charlottetown data). However, it would be expected that over a longer experimental period the potato-containing rations would maintain a higher level of production.

CONCLUSIONS

From the data reported here, it is concluded that potatoes can replace grass silage (on an equal T.D.N. basis) in the ration of dairy cows provided the protein content of the grain mixture fed with the potatoes is increased. While efficiency was not affected, higher T.D.N. consumption was obtained when silage and potatoes were fed together than when silage was fed alone. If both silage and potatoes are available, it would seem to be better practice to feed both together rather than to replace one with the other. This is particularly true if the silage is not of superior quality.

Increasing the protein of the grain mixture fed with potatoes from 15-16 per cent to approximately 20 per cent increased production of F.C.M. and S.N.F. but not of butterfat.

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THE INFLUENCE OF SIZE AND SURFACE CONDITION OF GRIT UPON THE DIGESTIBILITY OF FEED BY THE DOMESTIC FOWL[1]

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ABSTRACT

Two experiments were carried out with growing cockerels to study the effect of size and surface condition of grit upon digestibility. The criterion employed to evaluate these effects was the apparent digestibility of the individual proximate constituents. Comparisons were made between six sizes of grit ranging in diameter from 0.6 mm. to 5.0 mm., and between four grits of different surface conditions.

All grits utilized in this investigation significantly improved feed digestion. However, neither the size nor the surface condition of the grit influenced this response. Smaller sized grits, and grits displaying smoother-type surfaces were not retained within the gizzard to the extent of the rougher, larger sized grits; consequently a greater consumption of the former grits was experienced.

INTRODUCTION

It is well established that grit aids digestion in poultry (4, 9). Although numerous studies have demonstrated this biological effect, little has been mentioned regarding the influence of the physical properties, such as size and shape, of the grits upon this response.

With reference to grit size Scott and Heuser (8), in quoting Kaupp and Ivey (5), state that: "grits are held in the gizzard for some time where they are utilized for grinding, passing on through the remainder of the digestive tract only after they have been reduced by the grinding process to a size no longer capable of aiding in the attrition of the coarse particles of feed". This statement infers that grits lose their grinding value with decreasing size. Support for this theory is offered by Tepper *et al.* (11), who observed that fine granite wastes seriously interfered with efficiency of feed utilization in laying hens. Fritz (4), on the other hand, reported no consistent differences in digestibility coefficients when comparing the response of two adult birds to successive feedings of chick-sized and hen-sized grit. Rau and Platt (7) showed that size of grit particle had little effect upon feed utilization in adult birds. Balloun and Phillips (2) studied the effect of three types of grit upon growing chickens and found that grey granite, red quartzite and silica sand were of equal value. Their results showed, however, that the groups fed sand attained slightly better feed conversions than the others. Smith and MacIntyre (9) also presented data showing that silica sea sand was just as effective in aiding feed digestibility as hen-sized quartz or limestone grits.

Little evidence has been submitted regarding the effect of surface condition of grit on digestibility. Since the gizzard's action is one of grinding and crushing (10), it is reasonable to expect that a smooth particle may render the same service as a rough one. The observation made by Kaupp and Ivey (5), that "birds hold their weight and remain relatively healthy on either sharp or dull grit", appears to substantiate this view.

[1]Contribution No. 107, Research Branch, Canada Department of Agriculture, Nappan, N.S.

TABLE 1. — THE INFLUENCE OF GRIT FEEDING ON THE DIGESTIBILITY OF THE PROXIMATE CONSTITUENTS

Grit treatments	Digestibility of the proximate constituents (per cent)*									
	Organic matter		Crude protein		Crude fibre		Ether extract		Nitrogen-free extract	
Experiment 1 — Particle size	Before	After	Before	After[1]	Before	After	Before	After	Before	After
1 Sand#40	79.5	82.0	79.5	82.0	17.3	27.3	65.4	77.7	84.8	86.3
2 Sand#30	78.3	80.5	74.8	79.5	19.0	25.5	61.4	78.7	83.3	84.3
3 Quartz#30	79.2	80.7	78.6	81.2	14.8	21.6	67.1	73.7	84.1	84.2
4 Quartz#20	79.1	80.2	77.2	78.1	17.2	20.0	63.6	75.4	84.2	84.8
5 Quartz#10	79.0	81.7	79.0	82.4	18.6	27.1	68.4	80.9	83.3	85.3
Experiment 2 — Surface condition	Before	After	Before	After	Before	After	Before	After[2]	Before	After[3]
1 Sand#30	84.6	86.2	83.7	85.0	33.9	48.0	74.9	84.6	88.6	89.6
2 Quartz grit#10	83.5	86.6	83.7	83.0	33.3	45.2	76.5	86.8	87.5	90.2
3 Smooth pebbles#10	83.1	85.0	80.4	82.9	29.4	42.1	73.5	86.6	87.3	88.1
4 Rough pebbles#10	83.9	85.0	82.0	82.8	34.7	41.7	75.2	83.5	87.4	88.0

#No. mesh per inch
*Before and after grit feeding

[1]Covariance L.S.D. (P+0,05) = 3,58
[2]Covariance L.S.D. (P+0,05) = 2,83
[3]Covariance L.S.D. (P+0,05) = 1,22

The investigation reported herein was designed to study the effect of size and surface condition of grits upon digestibility in the growing chicken. The criterion employed as a measure of efficiency was the apparent digestibility of the individual proximate constituents.

MATERIALS AND METHODS

Two digestibility trials were carried out to measure the effect of grit size and surface condition. In the first trial comparisons were made between grit ranging in size from 0.6 millimetre to 5.0 millimetres, while the second trial was devoted to a comparison of grits displaying four different surface conditions.

In Experiment 1, 30 cross-bred (R. I. R. x L. S.) 10-weeks-old cockerels, having had no previous access to grit, were individually caged and assigned at random to five groups for subsequent grit feedings. The grits fed were No. 40 mesh sand, No. 30 sand, No. 30 quartz, No. 20 quartz (chick-size), No. 10 quartz (hen-size) and No. 5 quartz (turkey-size). Grit sizes were determined by passing the grit through screens of decreasing size, the screen upon which the grit finally came to rest determining the size reported. Birds of this age were unable to swallow the large particles in the No. 5 mesh category, so this treatment was removed.

In Experiment 2, 24 cross-bred (R. I. R. x L. S.) 8-weeks-old cockerels, having had no previous access to grit, were individually caged and assigned at random to four groups. Washed silica sea sand, insoluble quartz grit, smooth granite pebbles and shattered granite pebbles were used in this experiment. A quantity of smooth pebbles were shattered into jagged, rough-edged particles in a Braun Chipmunk Crusher*. The sand was screened to size No. 30 while the quartz grit, smooth pebbles and shattered pebbles were screened to size No. 10.

The birds of both experiments received a grain mixture consisting of equal parts whole oats, whole wheat and cracked corn. Each bird was offered 45 grams of feed twice daily. All grits were fed *ad libitum*. Upon initiation of each experiment the birds were starved for 24 hours, then fed the whole grain ration without grit for a period of 7 days. After 3 days on this ration, individual feces collections were carried out for 4 consecutive days. Following this, the birds were starved for 24 hours, then fed the whole grain ration with the prescribed grit treatment for 3 days prior to, and including, the second 4-day collection period.

Droppings were collected each morning and dried in an oven at 80° C. for 16 hours. Upon termination of a collection period, the feces from each bird were mixed, ground and sampled for analysis. Conventional proximate analyses were conducted according to A.O.A.C. methods (1). Nitrogen in the droppings was partitioned into fecal and urinary nitrogen by the method of Ekman *et al.* (3). Organic matter and nitrogen-free extracts attributable to intestinal and urinary sources were calculated, using the method outlined by Olsson and Kihlen (6). The digestibility coefficients of the proximate constituents were determined before and after

*Braun Corp., Los Angeles, Calif. Courtesy of E. Milligan, Nova Scotia Agricultural College, Truro, N.S.

the feeding of grit, thus allowing each bird to be used as its own control. At the conclusion of each experiment the birds were sacrificed and their gizzard contents examined.

RESULTS AND DISCUSSION

The average coefficients of apparent digestibility are presented in Table 1. In Experiment 1 the feeding of the grits caused a significant increase in the digestibility of all proximate constituents. In Experiment 2 all but the crude protein fractions were significantly increased (Table 2-A)*. The disparity between the digestibilities of the control groups of Experiments 1 and 2 may be attributed to the environmental conditions at the time of the experiments and the age and genetical background of the chickens on test.

The data of Experiment 1 indicate a slightly greater improvement in digestibility where the extreme sizes of grit were fed, i.e. No. 40 sand and No. 10 quartz grit. However, analysis by the covariance technique reveals that, with the exception of the protein digestibility of treatment 4, all sizes of grit effected an equal response (Table 2-B)**. The significantly lower protein digestion in treatment 4 cannot be explained. Covariance

*Goulden, C. H. 2nd ed. Analysis of paired data by "t" test.
**Goulden, C. H. 2nd ed. Analysis of covariance.

TABLE 2.—SUMMARY OF STATISTICAL ANALYSES OF THE COEFFICIENTS OF APPARENT DIGESTIBILITY

A: "t" test of paired values[1]

	EXPERIMENT 1			EXPERIMENT 2		
	Calculated "t"	P = .01 2.80	P = .05 2.06	Calculated "t"	P = .01 2.81	P = .05 2.07
Organic matter	6.28	Highly significant		6.41	Highly significant	
Crude protein	4.21	"	"	1.50	No sig. difference	
Crude fibre	3.88	"	"	4.99	Highly significant	
Ether extract	4.74	"	"	15.24	"	"
Nitrogen-free extract	2.94	"	"	3.98	"	"

B: "F" values of adjusted treatment analyses[2]

	EXPERIMENT 1			EXPERIMENT 2		
	Calculated "F"	P = .01 4.89	P = .05 3.06	Calculated "F"	P = .01 6.51	P = .05 3.74
Organic matter	0.51	No sig. difference		1.09	No sig. difference	
Crude protein	26.68	Highly significant		0.76	" " "	
Crude fibre	2.60	No sig. difference		0.93	" " "	
Ether extract	1.18	" " "		9.83	Highly significant	
Nitrogen-free extract	2.54	" " "		15.48	"	"

[1]Analysis of paired data by "t" test. (Goulden, C. H. 2nd ed.)
[2]Analysis of covariance. (Goulden, C. H. 2nd ed.)

TABLE 3. — RETENTION OF GRITS AFTER *AD LIBITUM* FEEDING FOR 4 DAYS

Grit treatments	Body weight	Gain	Grit consumption	Grit retained in gizzard
	gm.	gm.	gm.	per cent
Experiment 1 — Particle size[1]				
Sand#40	1391	110	78	0.49
Sand#30	1424	95	70	2.83
Quartz#30	1411	127	64	4.06
Quartz#20	1321	71	66	13.40
Quartz#10	1391	106	31	50.07
Experiment 2 — Surface condition[2]				
Sand#30	1165	105	53	2.12
Quartz#10	1161	88	24	45.89
Smooth pebbles#10	1185	97	16	21.69
Rough pebbles#10	1182	110	25	53.44

[1]Average of 5 birds
[2]Average of 6 birds
#No. mesh per inch

analysis of the data of Experiment 2 reveals significant differences within the ether extract and nitrogen-free extract fractions. If these differences are meaningful it would appear that the pebbles, smooth or shattered, are less efficient than the sand or quartz grit. However, to consider differences between grit treatments as real, when relying upon statistical significance in two out of five measured fractions, would be unwise.

Data illustrating the retention of the various grits is presented in Table 3. Voluntary grit consumption declined significantly with increasing grit size (Experiment 1). However, grit retention on a per cent ingested basis increased with increasing grit size. The data of Experiment 2 substantiate this observation. In addition, a comparison between the smooth and rough No. 10 mesh grits in this latter experiment reveals a lesser consumption and a higher percentage retention of the rougher type particles. Therefore, it may be expected that upon feeding moderately large, rougher type grits, even though less is consumed, greater quantities of the material will be retained within the gizzard.

The suggestion by Kaupp and Ivey (5), that the gizzard is highly selective in its retention of grits, was not supported by observation in these trials. Grit particles of various sizes passed through the gizzard, some having experienced no measurable reduction in size or shape when recovered from the feces. Furthermore, at any given time a wide range of particle sizes (No. 80-No. 10 mesh) were found within the gizzard.

Notwithstanding the differences in grit consumption and retention mentioned above, the present investigation has shown that responses attributable to the various sizes of grit studied were equal in magnitude. Responses between surface conditions of grit have also proven rather uniform. This would suggest that, as long as grit particles are present in the gizzard, they will aid digestion in the growing chicken regardless of their size or shape.

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THE NUTRITIONAL VALUE OF INCREASED LEVELS OF PROTEIN RESULTING FROM NITROGEN FERTILIZATION OF BARLEY[1]

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ABSTRACT

Samples of barley having low, medium, and high protein contents were obtained from field fertilizer experiments conducted during 1957 and 1958. The nutritive values of these grains were compared in a feeding trial employing rats as the test animal, and by a semi-quantitative chromatographic estimation of 13 amino acids in the grains. For the feeding experiment all diets were supplemented with minerals and vitamins. Each grain sample was fed with and without added lysine. Animal growth and food efficiency improved with increase in protein levels and with addition of lysine. The 13 amino acids determined accounted for approximately two-thirds and four-fifths of the total protein in the 1957 and 1958 grains respectively. Possible causes of these differences are discussed. The analytical data revealed that percentages of 9 essential amino acids in barley protein were approximately double the amounts reported by other analytical procedures. Compared to previously reported data, there were some noteworthy variations for individual amino acids. There may be practical applications of the procedure used for amino acid determinations in evaluating the protein quality of feed grains. The availability of such a technique could be very helpful to plant breeders concerned with the production of feed grain varieties. The feeding experiment established the nutritive importance for rats, and presumably for swine, of grain protein increases resulting from nitrogen fertilization.

INTRODUCTION

In a previous paper (10) it was reported that a top-dressing of fertilizer nitrogen applied to field-grown oats and barley shortly after the shot-blade stage substantially increased the protein content of the grain and the production of grain protein per acre. For practical as well as scientific reasons it is desirable to know the nutritive value of protein in grain grown following nitrogen fertilization as compared to that in unfertilized grain.

It is known that a general relationship exists between the protein content of cereal grains and their nutritive value for rats and swine, such a relationship having been reported by Bentley *et al.* (2), Maynard and Loosli (9), and McElroy *et al.* (12, 13). Although increases in the protein content of cereal grains resulting from nitrogen fertilization have been widely reported, there have been very few experiments to study the nutritive importance of such protein increases. One report (7) from Scotland states that protein increases in wheat resulting from fertilizer nitrogen applied as a top-dressing were accompanied by improved nutritive value of the grain.

It has been established that fertilizer treatments may affect the quality as well as the quantity of grain protein. Renner *et al.* (15) have reported variations in the proportions of 9 essential amino acids in wheat and barley as a result of fertilization and cropping sequence. The report revealed that

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an increase in quantity of protein was not always accompanied by an increase in protein quality as measured by the proportion of the 9 essential amino acids determined. The possible nutritive significance of these variations in the proportions of the 9 essential amino acids was not clarified by feeding experiments conducted subsequently by Bentley *et al.* (2) using wheat grown at the same location, although differences in the nutritive value of the grains were found.

This report is concerned with rat feeding experiments and amino acid determinations intended to compare the nutritive values of barleys differing in protein content as a result of top-dressed nitrogen fertilizer applications.

MATERIALS AND METHODS

Rat Feeding Experiment

Samples of barley varying in protein content were obtained from field fertilizer experiments conducted in north-central Alberta during the summers of 1957 and 1958 (10). For each year three sets of grain samples, designated hereafter as *low*, *medium*, and *high protein*, were prepared. Each grain sample was a composite prepared by bulking equal weights of barley from four or five of the field trials. Low protein samples were all obtained from unfertilized plots, while medium and high protein grain came from adjacent plots in the same fields to which ammonium nitrate fertilizer supplying 20, 40 or 60 pounds of nitrogen per acre had been applied (10). Each of the six bulk grain samples were divided into two equal portions, one of which was supplemented with 0.9 per cent lysine. This allowed a comparison of the nutritive value of the barleys with and without lysine supplementation. The 12 rations are listed in Table 1. Complete vitamin and mineral supplements as used by Sibbald *et al.* (16) were added in all cases.

Feeding trials were conducted under uniform conditions in an animal room used only for rats. A total of 48 female weanling rats of the Sprague-

TABLE 1. — DIETS USED IN RAT FEEDING EXPERIMENT[1]

Diet number	Composition	Grain protein[2] per cent
1	1957 — Low protein barley	10.8
2	1957 — Medium protein barley	14.7
3	1957 — High protein barley	16.9
4	1957 — Low protein barley plus 0.9% L-lysine	10.8
5	1957 — Medium protein barley plus 0.9% L-lysine	14.7
6	1957 — High protein barley plus 0.9% L-lysine	16.9
7	1958 — Low protein barley	10.1
8	1958 — Medium protein barley	14.0
9	1958 — High protein barley	16.6
10	1958 — Low protein barley plus 0.9% L-lysine	10.1
11	1958 — Medium protein barley plus 0.9% L-lysine	14.0
12	1958 — High protein barley plus 0.9% L-lysine	16.6

[1]All diets received complete vitamin and mineral supplements (16) at the rates of 1% and 4% respectively
[2]N x 6.25

Dawley strain were used as test animals and were allotted to metal cages in pairs, with two pairs being used as replicates for each diet. All animals were weighed individually at the beginning and the end of the 2-week feeding period. Food was supplied *ad libitum*, the food consumption being recorded. An analysis of variance was performed on the data obtained.

Chromatographic Analyses

Semi-quantitative determinations were made for amino acids or amino acid pairs in the barley employing a chromatographic technique. One-gram samples of the six grains used in formulating the diets were prepared for chromatographic analysis by refluxing with 6 *N* HCl for 20 hours. This is a common procedure for protein hydrolysis (1, 6). The resulting hydrolysates were filtered and the acid was removed by twice evaporating to dryness on a steam bath. The residue was dissolved in 5 ml. of 50 per cent iso-propyl alcohol. This solution was stored at 0°C. to remove salts, and to prevent spoilage. Using a standardized micropipette two-lambda aliquots were spotted on Whatman No. 1 filter paper for chromatographic separations. The chromatograms were given two irrigations of 24 hours each using a solvent composed of butanol:acetic acid:water in a 4:1:5 ratio. Colour was developed with a spray of 2 per cent ninhydrin in water-saturated butanol. Direct densitometric comparisons were made of the amino acids separated on chromatograms (1, 3, 4, 5). Maximum density readings were made of the spots with a Photovolt Densitometer. Calibration curves were prepared using standard solutions of amino acids having concentrations of 4, 6, 8 and 10 micromoles per millilitre. Replicate determinations on both standard solutions and unknowns were consistently in good agreement as differences between the highest and lowest values, for four or more determinations, were seldom more than 20 per cent, and were frequently less than 10 per cent.

TABLE 2.—EFFECT OF PROTEIN LEVEL AND LYSINE SUPPLEMENTATION ON RAT GROWTH, FOOD, AND PROTEIN EFFICIENCY

Diet number	Average rat gain /14 days gm.	Av. food consumed /14 days gm.	Av. food /gm. gain gm.	Av. protein consumed /gm. gain gm.
1	14.0	98	7.0	0.76
2	26.9	120	4.5	0.65
3	30.6	127	4.2	0.70
4	23.4	111	4.7	0.56
5	39.1	117	3.0	0.47
6	50.0	131	2.6	0.46
7	20.5	122	6.0	0.60
8	33.1	129	3.9	0.54
9	30.1	113	3.8	0.63
10	14.4	91	6.3	0.70
11	42.0	126	3.0	0.44
12	51.3	137	2.7	0.47

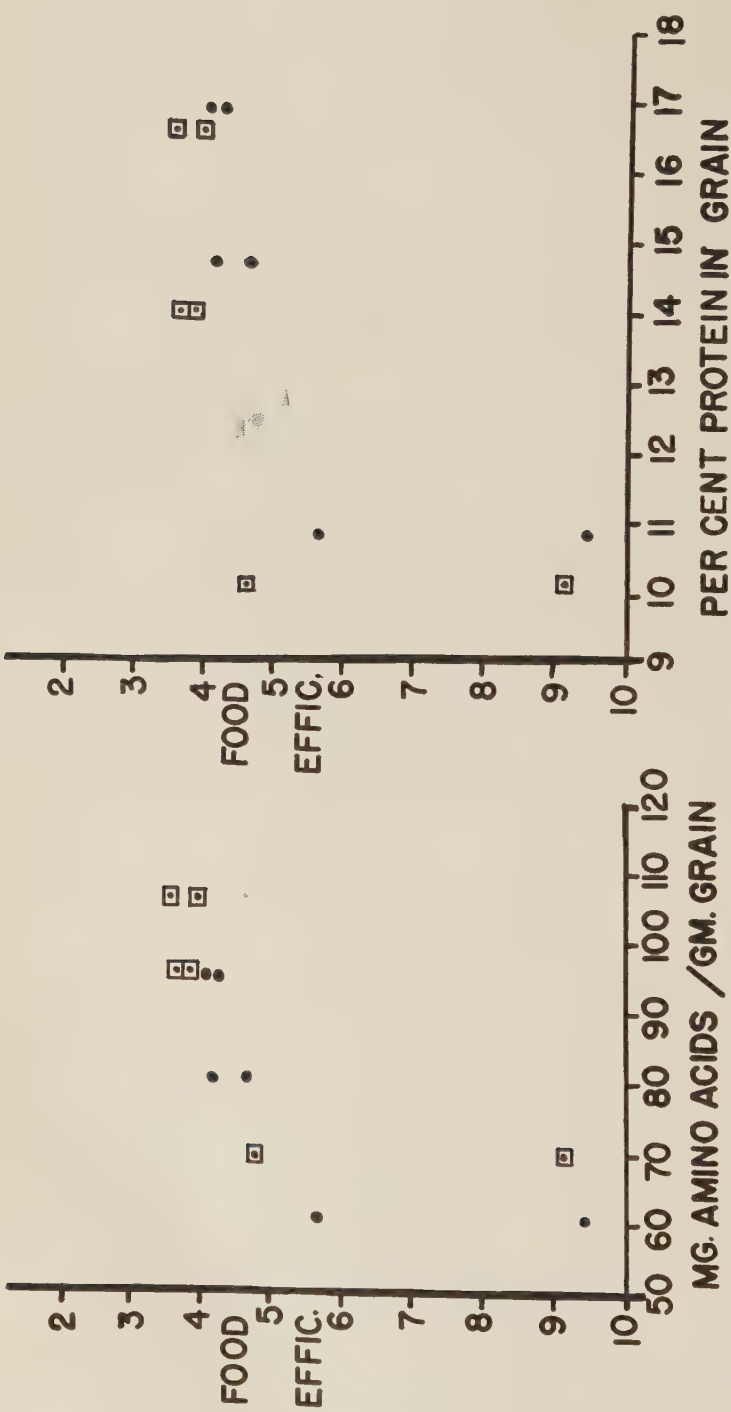

FIGURE 1. The relationship between food efficiency, essential amino acids, and protein content of barley not supplemented with lysine. (Data are for individual rat cages).

Two dimensional chromatography as described by Hughes *et al.* (8) was utilized to separate and estimate the proportion of those amino acids that ran closely together in the butanol:acetic acid:water mixture. This enabled a more complete identification of the amino acids in the grain protein and the determination of their proportions. All data for the barley analyses and for the diets fed are on the basis of oven-dry weight of grain.

RESULTS AND DISCUSSION

Feeding Experiment

The data obtained in the feeding experiment are presented in Table 2 and the analyses of variance for these data are given in Table 3. The variable food efficiency data of Table 2 and of Figures 1 and 2 may be attributed primarily to poor quality of the lower protein diets and to animal differences. In several instances one animal gained more than twice as much as the other one in the same cage. In Table 3 only selected components making up the treatment variances are reported because of their special interest and significance. In general both rate of gain and food efficiency were strongly influenced by the protein content of the grain making up the diets and, with one exception, lysine supplementation increased gains and food efficiency. The effects of lysine supplementation of the medium and high protein content diets are especially noteworthy because rather large differences in gains occurred with comparatively small variations in food consumption. When the diets were not supplemented with lysine,

TABLE 3. — ANALYSIS OF VARIANCE FOR FEEDING EXPERIMENT

Source	Degrees of freedom			Mean square variance	Variance ratio	
					Calculated	For signif. ($P<0.05$)
1. *For Animal Gains*						
Total	23					
Replicates		1		90,774*	7.98	4.84
Treatments		11		124,980**	10.99	2.82
Protein level			2	443,190**	38.96	3.98
Lysine			1	275,633**	24.23	4.84
Protein x lysine			2	69,775*	6.13	3.98
Error		11		11,375		
2. *For Food Efficiency*						
Total	23					
Replicates		1		661		4.84
Treatments		11		707*	4.01	2.82
Protein level			2	2,995**	17.02	3.98
Lysine			1	1,261*	7.16	4.84
Error		11		176		
3. *For Protein Efficiency*						
Total	23					
Replicates		1		0.0631		
Treatments		11		0.0318	1.87	2.82
Protein level			2	0.0740*	4.35	3.98
Lysine			1	0.1276*	7.5	4.84
Error		11		0.0170		

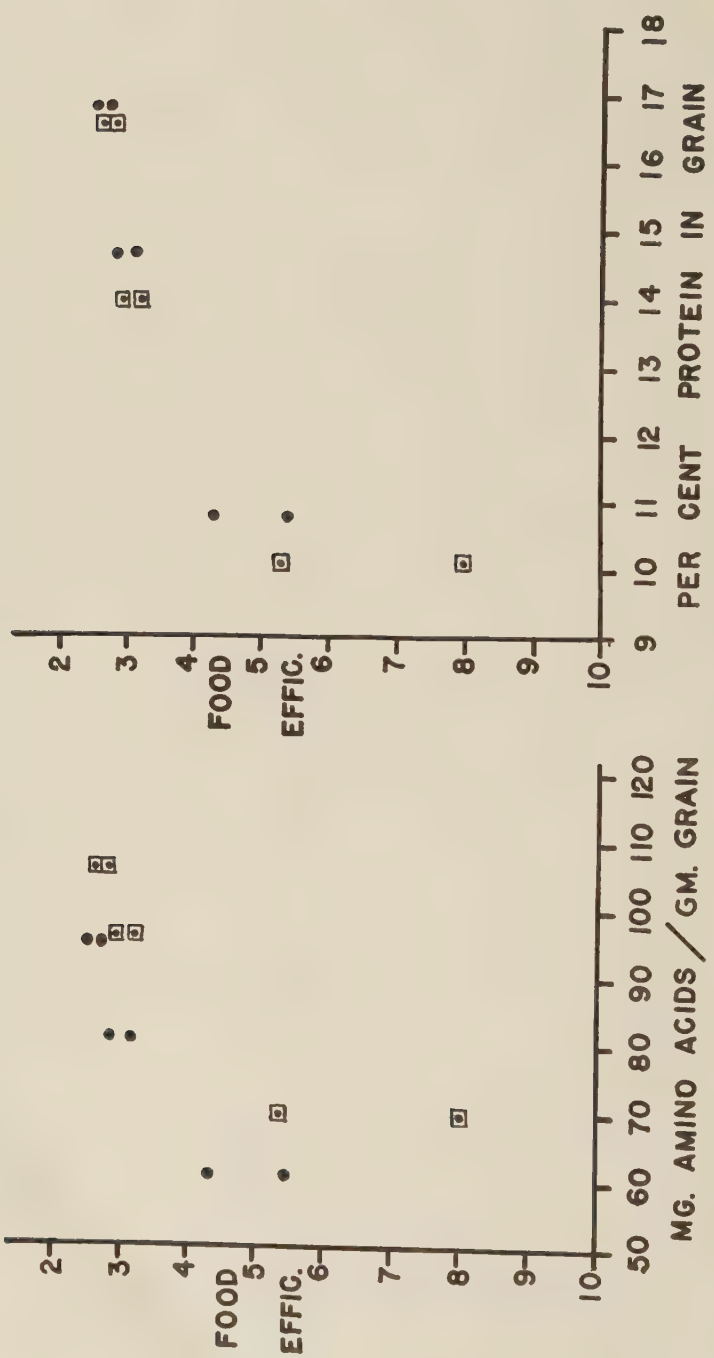

FIGURE 2. The relationship between food efficiency, essential amino acids, and protein content of barley supplemented with 0.9 per cent lysine. (Data are for individual rat cages).

animal gains and food efficiencies were quite similar for medium and high protein grains. The preceding differences are of such magnitude that they may be of practical importance in swine feeding as rats and pigs have similar amino acid requirements. Protein efficiency, the amount of protein consumed per unit of animal gain, was better for 1958 grains than for 1957 grains and, with one exception, was considerably increased by lysine supplementation of the diets.

The inconsistent results for diet 10 may be associated with biological variation already mentioned but it is possible that the lysine supplement caused an amino acid imbalance since that grain was found to have a slightly higher lysine content than the other grains which were used. Recent investigations (17) have established the possibility of such an effect due to amino acid imbalance.

Amino Acid Determinations

Data from the amino acid determinations made on the six barley samples are presented in Table 4. Six of the amino acids were not adequately separated by the unidimensional chromatography and separation of those pairs of amino acids was achieved subsequently by two dimensional chromatography (8) and the appropriate values assigned to the separate amino acids shown in Table 4.

In addition to the amino acids listed in Table 4, aspartic acid, glycine, and serine were identified as being present but they were not quantitatively estimated by densitometry because of unsatisfactory separations or low concentrations. Two and probably three ninhydrin compounds with R_f values above leucine were also present.

In Table 4 the results are expressed as percentages of the total protein (N x 6.25) and on that basis the 13 amino acids determined account for approximately two-thirds and four-fifths of the total protein in the 1957 and 1958 grains respectively. It is surprising to find such a large difference in the composition of the barley protein because the grains were grown on successive years under similar field conditions, including position in the cropping sequence, and because each sample represented a composite with four or five approximately equal components. The differences may be associated with the different barley varieties concerned in the 2 years. These varieties were: O.A.C. 21 (3 farms), Manchurian (1 farm), and unknown (1 farm) in 1957; and O.A.C. 21 (1 farm), Gateway (2 farms), and Montcalm (1 farm) in 1958. It has been established that some varieties of barley grown in Alberta differ in content of certain essential amino acids (14) and a comparison of other Alberta data (11, 15) also reveals differences in amino acid proportions between some barley and wheat varieties. There is little doubt that the differences between the 1957 and 1958 grains are real because all samples were prepared and analysed together under uniform conditions including standard times. The higher amino acid content of the 1958 barley was primarily due to variations in the amounts of 8 of the amino acids because each of cystine, tyrosine, phenylalanine, isoleucine, and leucine were present in approximately the same amounts in all six barley samples.

It is possible that growing season conditions were responsible for the higher proportion of determined amino acids in the 1958 grain. However, McElroy *et al.* (11) and Renner *et al.* (15) did not find similar yearly variations when most of the same amino acids were determined in single varieties of Alberta grains.

The data in Table 4 differ greatly from previous Alberta results for the percentage of 9 essential amino acids in barley protein. An average of 33-34 per cent of these 9 essential amino acids in barley with a range of 28-36 per cent has been reported (11, 14, 15). The value of 55-69 per cent in Table 4 are about double those percentages. The more vigorous hydrolysis employed in this study may explain the differences. It is known that several amino acids are affected by acid hydrolysis: tryptophane is destroyed and the yields of serine, threonine and methionine are reduced. However, since a 6 N hydrolysis is now utilized by many workers (1, 6) the results submitted are felt to be comparable to most recent reports. The use of a chromatographic technique for amino acid analyses as compared to the microbiological assay methods in previous studies is probably a factor contributing to the difference in results.

There are, however, noteworthy variations to the general comparison that has been made. Arginine, leucine, and phenylalanine were reported by other workers (11, 15) to be present in amounts rather similar to those in Table 4 while the amounts of threonine, valine, methionine, and isoleucine

TABLE 4. — AMINO ACID CONTENT OF BARLEY PROTEIN (N X 6.25) DETERMINED BY CHROMATOGRAPHY

Constituent[1]	1957 barley protein level			1958 barley protein level		
	low	med.	high	low	med.	high
Protein, per cent	10.8	14.7	16.9	10.1	14.0	16.6
	Per cent of amino acid in protein					
[2]Leucine	4.2	4.0	3.8	4.6	4.4	4.2
[2]Phenylalanine [3]	3.5	3.5	3.8	3.6	3.9	3.8
[2]Isoleucine	12.9	12.2	13.0	12.5	13.4	13.1
[2]Methionine [3]	2.1	2.2	2.5	3.0	3.2	2.9
[2]Valine	7.2	7.8	8.7	10.3	11.1	10.1
Tyrosine	2.5	2.7	2.9	2.5	2.5	2.7
Alanine	6.3	5.8	5.6	7.9	6.3	6.5
Glutamic acid [3]	3.2	2.7	2.5	3.8	3.4	2.8
[2]Threonine	12.8	10.9	10.2	15.1	13.5	11.4
[2]Arginine	4.8	4.9	5.4	8.2	7.1	6.8
[2]Histidine	3.0	3.1	3.2	4.3	4.4	4.1
[2]Lysine	4.4	4.6	4.4	6.3	5.8	5.9
Cystine	1.0	1.5	1.2	1.0	1.4	1.5
[2]Total for 9 essential amino acids	55.9	54.7	56.2	68.9	68.2	63.8
Total for 13 amino acids determined	67.9	65.9	67.2	83.1	80.4	75.8
	mg. per gm. of grain					
Total for 9 essential amino acids	60.4	80.4	95.0	69.6	95.5	105.9
Total for 13 amino acids determined	73.3	96.9	113.6	83.9	112.6	125.8

[1]Amino acids listed in order of ascent in chromatogram
[2]Essential amino acids
[3]Separated by two dimensional chromatography

were only one-half to one-quarter of those reported in that table. However, these differences are probably not entirely due to the methods of hydrolysis or to the analyses procedures. The data of Renner *et al.* (15) were obtained by procedures essentially the same of those employed by McElroy *et al.* (11) and there are definite differences between these reports in the relative proportions of many amino acids in both wheat and barley. Pethybridge (14) making a specific comparison of amino acids in several grain varieties also found differences in amino acid proportions.

There appears to be a clear relationship between the level of grain protein and the levels of 3 of the amino acids reported in Table 4. In every instance the percentages of threonine, glutamic acid and leucine in the protein decreased when the total protein increased. It is rather unlikely that this decrease is of nutritive significance because the essential amino acids threonine and leucine are usually present in adequate quantities in barley protein. Data for lysine in Table 4 do not show the definite inverse relationship to protein content mentioned in other reports (11, 14). For cystine, tyrosine, phenylalanine, and isoleucine, there are weak trends to increase as grain protein increased while for alanine there was a slight tendency to decrease when barley protein increased.

The food and protein efficiencies (Table 2) for 1958 barleys without a lysine supplement were in every case higher than those of the corresponding 1957 samples in spite of a slightly higher total nitrogen content of the 1957 samples. Although the differences were not great, this pattern suggests that the differences in total amino acids reported in Table 4 are of nutritive significance. These relationships are more evident in Figure 1 where food efficiency appears to be more closely related to the amount of the 9 essential amino acids than it is to protein content of the grain. Such a result is logical since, among the essential amino acids determined, 8 were present in larger amounts in 1958 grain than in the 1957 samples. Moreover, lysine and methionine, which are among the most frequently limiting amino acids for rats or swine, and arginine which is occasionally limiting for poultry, were all present in substantially larger amounts in the 1958 barley. However, Figure 2, which is concerned with lysine-supplemented grain, suggests that food efficiency is more closely related to protein content than it is to amounts of the 9 essential amino acids determined. The difference between relationships applying in Figures 1 and 2 probably results from the limiting effect of lysine in the food conversion of the rats fed the diets without added lysine as illustrated in Figure 1. These data suggest, as would be expected, that determination of the 9 essential amino acids may be a better measure of the nutritional value of barley than is a total protein determination.

The foregoing observations have several important implications. Barley varieties may differ appreciably in their amino acid proportions and this may be of nutritive significance in practical agriculture. Climatic and/or other environmental conditions may also affect the amino acid proportions of barley. Since the method of amino acid determination employed here gave values for several essential amino acids substantially different to those reported by the microbiological assay technique, investigation is warranted

to compare the relative suitability of the two methods for evaluating protein quality of feed grains.

At present feeding experiments are necessary to determine accurately the nutritive value of grain proteins for some classes of livestock. If it were possible to make such evaluations on the basis of amino acid determinations, that knowledge would be of importance to plant breeders concerned with producing grain varieties to be used for feeding purposes. Because of the considerable economic importance of this possibility it merits close investigation.

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WHOLE RAPE SEED AS AN ENERGY SOURCE IN FINISHING DIETS FOR ROASTER TURKEYS

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ABSTRACT

Broad Breasted Bronze male turkeys, 20 weeks of age, were fed all mash finishing diets with and without whole rape seed as an energy source. Whole rape seed, at a level of 22.8 per cent, was substituted for all of the soybean oil meal and part of the ground wheat in the ration. Each treatment was replicated six times with 12 male turkeys per replicate. At the end of the 4-week feeding period the following results were evident: 1) no statistically significant differences in feed conversion ($P > 0.05$), and 2) highly significant improvements in carcass finish and live weight gains ($P < 0.01$) for those birds receiving the diet containing whole rape seed.

INTRODUCTION

Andrews and Schnetzler (1), Kempster and Turner (6), Reineke *et al.* (7), and Blakely and Anderson (2), have shown that the goitrogenic compound thiouracil would result in increased fattening when included in the diets of chickens and turkeys. Rapeseed oilcake meal is known to contain an active goitrogenic principle, [Blakely and Anderson (3) and many others]. However, Blakely *et al.* (4) have shown that this supplement does not possess any special fattening properties when fed at levels of 15 and 25 per cent to turkey broilers and mature cockerels. Jowsey *et al.* (5) reported that the addition of 10 per cent stabilized tallow to increase the energy value of finishing rations for roaster turkeys improved live weight gains and feed efficiency, and raised carcass score. The present experiment was undertaken to determine if the high oil content of whole rape seed would furnish a satisfactory source of dietary energy for roaster turkey finishing rations.

MATERIALS AND METHODS

The experiment was conducted in the floor pens of a large brooder house. The pens were identical in size and provided approximately 8 square feet per bird. The building was equipped with automatic ventilation and was maintained at a temperature of 60°F. to 65°F. Two dietary treatments of equal protein content were established. *Diet 142A* was a relatively low energy ration containing soybean oil meal as a protein supplement and ground wheat as the main cereal grain. *Diet 142B* was a high energy diet in which 22.8 pounds of whole rape seed replaced 19 pounds of wheat and 3.86 pounds of soybean oil meal. The whole rape seed supplied approximately 10 per cent oil to the ration. Each treatment was replicated six times with 12 male Broad Breasted Bronze turkeys per replicate. The experiment was commenced when the birds were 20 weeks of age and continued for a 4-week period. Experimental diets are shown in Table 1.

Individual body weights were obtained at the beginning and end of the experiment. Group feed consumption was recorded weekly for each replicate. At the conclusion of the experiment the birds were processed

TABLE 1. — EXPERIMENTAL RATIONS

Ingredients		Diet numbers	
		142A	142B
		%	%
Barley, fine ground		14.29	14.29
Wheat, medium ground		70.00	51.00
Alfalfa meal		2.00	2.00
Meatscraps (55%)		2.86	2.86
Rape seed, whole		—	22.86
Soybean oil meal (solvent, 44%)		3.86	—
Dicalcium phosphate		1.43	1.43
Limestone, fine ground		1.29	1.29
KI-Mn-limestone premix[1]		0.43	0.43
Salt		0.43	0.43
Granite grit#3		1.00	1.00
Vitamin A premix (1,000 I.U./gm.)		1.00	1.00
Vitamin D3 premix (200 I.U./gm.)		1.00	1.00
Riboflavin premix (0.1%)		0.29	0.29
Aurofac-10, (10 gm. Aureomycin/lb.)		0.10	0.10
3-nitro, 4-hydroxyphenylarsonic acid premix (10% 3-nitro)		0.05	0.05
		100.00	100.00
Calculated composition:			
Crude protein	%	16.20	16.20
Calcium	%	1.36	1.40
Phosphorus	%	0.75	0.80

[1]688 p.p.m. I_2, 1.092% Mn., 37.2% Ca.

on a commercial eviscerating line and were scored for finish by being assigned numerical grades from 1 to 5, with 5 being the highest score. Gross energy values for the diets and major ingredients were obtained with a Parr Oxygen Bomb Calorimeter. A comparative gross energy value was also obtained on the 10 per cent tallow diet (144A) used by Jowsey *et al.* (5).

A preliminary investigation into the possibilities of pelleting diets containing high levels of whole rape seed was conducted by having a mixture consisting of 80 per cent ground wheat and 20 per cent whole rape seed processed through a commercial pellet mill. A portion of the resulting pellets was also checked for the development of rancidity due to the expressed oil. The laboratory of Swift Canadian Company, St. Boniface, Manitoba, kindly co-operated in determining rancidity.

RESULTS AND DISCUSSION

The effects of the diets on live weight gains, feed efficiencies and carcass scores are shown in Table 2. An analysis of variance of live weight gains and carcass scores showed highly significant differences in favour of the whole rape seed treatment. Feed consumption data showed an improvement in feed efficiency for the rape seed treatment, but the difference was not statistically significant.

TABLE 2. — THE EFFECT OF THE DIETS ON WEIGHT GAINS, CARCASS SCORE, FEED CONSUMPTION AND FEED CONVERSION

Diet no.	Whole rape seed	Gain	Carcass score	Feed consumption	Feed/ gain
	%	lb.	(5 > 1)	lb.	
142A	—	4.11	2.48	23.32	5.71
142B	22.8	4.46	3.12	24.30	5.55
Differences		0.35	0.64	0.98	0.16
Differences significant at		1%	1%	N.S. (P = 0.05)	N.S. (P = 0.05)

TABLE 3. — GROSS ENERGY VALUE OF DIETS

Diet no.	Dietary variables		Gross energy value[1]	Ether extract
	Tallow	Rape seed		
	%	%	Cal./lb.	%
142A	—	—	1927	1.54
142B	—	22.8	2190	11.98
144A[2]	10	—	2206	12.50
Rape seed	—	—	3112	40.74
Soybean meal	—	—	2093	1.19
Ground wheat	—	—	2025	1.52

[1]Parr Oxygen Bomb Calorimeter
[2]High energy diet used by Jowsey *et al.* (5)

Table 3 gives the gross energy and ether extract values for the experimental diets. The 10 per cent tallow diet used by Jowsey (5) was included for comparative purposes. It can be seen that the high energy rape seed diet compared favourably in gross energy value with the high energy tallow diet.

The pellets produced from the mixture of ground wheat and whole rape seed were tested manually for hardness. They proved to be somewhat softer than regular commercial poultry pellets, but under normal handling conditions did not break down unduly.

Results of the rancidity determination showed that the pelleted mixture did not develop rancidity until after 83 days' storage at room temperature. No rancidity determinations were made on pellets produced from a complete diet containing whole rape seed.

The results of this experiment would indicate that whole rape seed could be a satisfactory source of energy for roaster turkey finishing diets.

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A COMPARISON OF FIBROUS FEEDSTUFFS IN NON-RUMINANT RATIONS

EFFECTS ON GROWTH RESPONSES, DIGESTIBILITY, RATES OF PASSAGE AND INGESTA VOLUME

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ABSTRACT

Wheat bran, wheat straw, alfalfa, oat hulls, beet pulp, corn cobs and cellulose were added to basal diets at levels of 8, 16, 24 and 32 per cent and, in a second experiment, at six levels of digestible energy to permit approximately isocaloric comparisons in the range of 2.2 to 3.4 digestible kilocalories per gram of feed dry matter. All diets were designed to be nutritionally adequate on the basis of nutrient content per unit weight of diet. Weanling mice were fed the diets during 14-day growth tests.

Digestibility coefficients for the energy fraction were obtained: bran 42; wheat straw 0; alfalfa 37; oat hulls 10; beet pulp 41; corn cobs 14, and cellulose 0 per cent. Estimations of the digestibility of the basal ration by regression methods indicated associative effects, with corn cobs depressing basal digestibility from 89 to 85 per cent and beet pulp, alfalfa and oat hulls depressing it to about 86 per cent.

Varied responses were obtained to isocaloric diets depending on the bulk source. For example, on diets containing 2.2-2.4 digestible Calories/gm., mice fed diets containing wheat straw often failed to survive, those fed diets containing beet pulp or cellulose did poorly, but gains of 70 per cent of normal were obtained when wheat bran or oat hulls was the diluent.

Relative rates of passage of ingesta were computed by a method involving consideration of feed intakes, energy digestibility, maintenance requirements and weight gains over a fixed period. Bran rations had the highest passage rates; wheat straw, alfalfa and beet pulp the lowest. *In vitro* measurements indicated that the latter feeds were least capable of swelling in water and presumably occupied less space in the stomach. However, wheat straw and alfalfa tended to retain their physical characteristics throughout digestion.

The results of these experiments emphasize the complexity and the importance in non-ruminant nutrition of the fibrous or bulk components of the ration as they influence available energy, feed intake, volume of ingesta at various levels in the gastrointestinal tract, rate of passage and microbial activity.

INTRODUCTION

Following attempts to modify the nutritive value of rations based on wheat by the incorporation of cellulose and agar (2) it became increasingly evident that further information was needed on the physical aspects of diet formulation. In the case of animals that do not possess rumens or functional ceca there is limited ability to utilize bulky feeds; hence, as fibre or bulk increases, available energy per unit weight of feed decreases and animal response generally declines correspondingly.

Since McMeekan (15) demonstrated the possibility of limiting daily gain and influencing carcass quality in bacon pigs by feed restriction, other investigators (1, 6, 7, 21 and others) have attempted to achieve the same result by incorporating fibrous diluents into rations self-fed to swine. Several reports have indicated, however, that growth responses in various species have been improved by the inclusion of fibrous materials such as cellulose, oat fibre and sawdust (2, 8, 9, 10, 14). At least part of such effects may be due to increased feed consumption (5, 12) which in turn may have resulted from a change in laxation rate as demonstrated by

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Hummel *et al.* (13) with children. Bohman *et al.* (4) have shown that adaptation in size of the digestive tract may also be involved.

Other investigators have reported wide variations in digestibility of fibre by non-ruminants (16, 22 and others) and, likewise, varying results have been obtained from the use of alfalfa and certain mill by-products of wheat in rations fed to swine and poultry (4, 17, 20). It is apparent that several factors are involved in the varying responses to the inclusion of fibrous materials. Among these are the nutrient contribution of the material in question; effects upon the physical behaviour of the ingesta throughout the length of the gastro-intestinal tract with special regard to modification of enzymatic, microbial and nutrient absorption activities; and, finally, the demonstrated (4) possibility of physiological adaptation to dietary density changes.

In view of this evident lack of fundamental knowledge about the nutritional significance of bulk in non-ruminant feeds two experiments were designed to study the interrelationships between growth rates, digestibility, feed utilization and certain physical characteristics of feed and feces.

MATERIALS AND METHODS

Experiment No. 1

This experiment was designed to test the effects of adding various levels of each of seven different fibrous feeds to low-fibre basal rations (Table 1). These fibrous feeds constituted 8, 16, 24 and 32 per cent of the ration by weight and were wheat bran, wheat straw, dehydrated alfalfa, oat hulls, beet pulp (containing 30 per cent molasses as purchased), corn cobs, or pure cellulose[1]. The diets were tested in a factorial design involving two basal rations: predominantly either wheat flour or oatmeal. The final diets in every case contained 20 per cent protein (using equal parts skim-milk powder and meat meal as supplement), 2 per cent brewers' dried yeast, 3 per cent minerals[2] and vitamins A and D[3]. The levels of supple-

[1]Solka-floc B.W. 100. Brown Corp., Montreal, Que.

[2]The mineral mixture was: bone meal 28, $CaCO_3$ 47, NaCl 25, KI-calcium stearate 0.02, $FeSO_4$ 2, $MnSO_4$ 0.05 and $CuSO_4$ 0.01 gm.

[3]The vitamin A and D supplement was oleum percomorphum in corn oil and was added to provide 6 I.U. of vitamin A and 0.85 I.U. of vitamin D per gram of ration.

TABLE 1. — DESIGN OF EXPERIMENT NO. 1, A STUDY OF 8, 16, 24, AND 32 PER CENT OF EACH OF SEVEN FIBRE SOURCES IN DIETS BASED ON EITHER WHEAT FLOUR OR OATMEAL

Fibre source	Wheat flour basal diet				Oatmeal basal diet			
	Level of fibre source in diet (%)				Level of fibre source in diet (%)			
	8	16	24	32	8	16	24	32
Wheat bran Wheat straw Alfalfa Oat hulls Beet pulp Corn cobs Cellulose	Three male mice randomly allotted to each of the 56 diets							

mentation with protein, minerals and vitamins were considered to be sufficient to make digestible energy the first limiting nutritional factor in any diet that should result in subnormal growth. All ingredients were finely ground to prevent feed sorting.

Experiment No. 2

This study was designed to test the effects, on growth rates, of the various fibrous feeds when incorporated to provide predetermined graded levels of digestible energy per unit weight of feed. The energy levels selected were 2.4, 2.6, 2.8, 3.0, 3.2 and 3.4 digestible Calories per gram of dry matter, but as shown later the actual values ranged from 2.2 to 3.4 because the final data on digestibility coefficients were not available at the time.

The basal diet employed in this experiment was: wheat (60 lb./bu.) 52, brewers' dried yeast 2, yeast whey (3) 2, soybean oil meal 13, fish meal (72 per cent protein) 14, skim-milk powder 13 and minerals[2] 4 per cent. The final diets, after incorporation of the bulky components, contained, according to published analyses, at least 16 per cent protein and adequate minerals and vitamins to render energy intake the first limiting factor in the low-energy diets.

Four mice were randomly allotted to each of the 42 diets in this experiment.

Animals and Management

Weanling male mice of Carworth Farms No. 1 strain, weighing initially 8.0-9.0 grams and between 18-23 days of age, were used. While on test they were housed in individual, wire-bottom, metal cages in batteries. Feed and water were provided *ad libitum*. The mice in the final one of the three replicates of Experiment No. 1 had their cages equipped for quantitative fecal collections during the last 10 days of the 14-day growth trial; hence feed and fecal records were kept for these mice.

The temperature of the mouse laboratory was maintained thermostatically at about 25°C.

Analyses

Basal diets, fibrous ingredients and the feces collected during Experiment 1 were analysed for gross energy by oxygen bomb calorimetry.

Energy Digestibility Studies

The energy digestion coefficients derived in this experiment were combined with those in a subsequent test* involving similar basal diets but with additional 'bulk' levels such as to obtain pronounced growth suppression at the upper levels. A total of 35 mice was used with each type of diluent. Regression equations were obtained for the relationship between percentage digestibility of energy in the diets fed and the level of 'bulk' (per cent) in the diets. From these equations the digestibilities of the basal and 'bulk' components were obtained.

Measurements of *weight per unit dry volume* were obtained on the major feed ingredients by pouring samples from a height of about 6 inches into a standard (Imperial) pint measure (3-inch diameter). After allowing

*Unpublished.

an overflow the surplus material was removed from the top by a single stroke with a spatula. The contents of the measure were weighed and duplicate readings averaged. *Apparent wet volume*, adopted as one feasible criterion of feed behaviour during the early stages of digestion, was determined by a modification of the method of Proctor and Wright (18). Three grams of feed were soaked at least 10 minutes in distilled water in a 100-ml. graduate cylinder; then the solid material was forced to settle under the gravitational effect of a close-fitting 100-gm. brass balance weight. The volume occupied by the impacted mass was assigned to the feed.

True volume of digestion residue was estimated *in vitro* by adding 3 grams of feed to 50 ml. of an enzyme solution[1] and then incubating the mixture for 24 hours at 37°C. with occasional agitation. A few drops of toluene were added at the beginning to inhibit bacterial action. Upon completion of incubation, 2 grams of celite were added and the mixture was filtered by suction through a metal thimble equipped with a 300-mesh brass screen bottom. Suction was continued arbitrarily for 30 seconds after the disappearance of the supernatant fluid in the thimble. The thimble and contents were then immersed in a known volume of water in a graduate cylinder. After reading the new volume, the tare was deducted and the *true* wet volume of the digestion residue was obtained to serve as an index of the *in vivo* feed residue in the final stages of digestion.

This procedure was adopted simply to provide an index of the bulkiness of the indigestible material as it might occur in the final stages of digestion. Admittedly this scheme fails to recognize the *in vivo* effects of metabolic excretory products or of microbial activity. It also differs appreciably from *apparent wet volume* in that *true volume* excludes most of the interparticle water.

Relative Rates of Passage of Ingesta

These were determined from the relationship between animal size and food consumed over a known period of time (adjusted for differences in digestibility and efficiency of digestible energy utilization). The first step involved determination of the digestible energy requirement for maintenance from the regression equation relating gains with digestible calorie intakes for the 56 mice used in the digestibility phase of the experiment. Having thus established a maintenance requirement for a mouse of average initial weight, a curve was drawn to the WEIGHT$^{.73}$ power to accommodate mice of different *average test weights*.

Next, the digestible calorie consumption in excess of maintenance needs was calculated and the efficiency of energy utilization for gains *per se* was determined in order to ensure that potential differences between bulk sources, in their effects on efficiency of energy utilization, were not overlooked. With this information it was possible to calculate the amount of digestible energy or feed that would have to be consumed in a given time to produce any desired increase in body weight. The results were used as indices of rates of passage.

[1]The enzyme solution was composed of 1000 ml. H_2O, 5 gm. pepsin, 50 gm. Rhozyme S (courtesy, Rohm & Haas Co., Philadelphia, Pa.), and 5 ml. conc. HCl. The pH of this solution was 3.1 but when mixed with the diets under test the pH varied between 3.5 and 4.6.

TABLE 2. — GROWTH AND FEED INTAKE RESULTS FROM EXPERIMENT NO. 1

Feedstuff	Level in diet	Gains	Feed intakes (dry matter)	Gains adjusted for difference in feed intake	Digestible Cal./gm. dry matter
	%	gm.	gm.	gm.	Cal.
Wheat bran	8	13.5	48	14.4	3.8
	16	12.9	46	13.5	3.6
	24	13.9	50	13.5	3.5
	32	14.8	53	13.7	3.3
Alfalfa	8	14.0	46	14.5	3.6
	16	13.0	47	13.5	3.5
	24	13.5	49	13.3	3.3
	32	11.9	47	12.1	3.1
Beet pulp	8	14.1	48	14.3	3.6
	16	13.2	47	13.5	3.5
	24	13.8	50	13.4	3.3
	32	12.0	47	12.4	3.1
Oat hulls	8	13.7	46	14.2	3.5
	16	12.8	47	13.2	3.3
	24	11.2	45	11.8	3.0
	32	7.9	47	8.1	2.7
Wheat straw	8	12.7	48	12.8	3.6
	16	12.2	49	12.0	3.3
	24	10.6	47	10.8	3.0
	32	6.1	38	8.5	2.7
Corn cobs	8	13.5	47	13.8	3.5
	16	12.9	52	12.1	3.2
	24	13.1	55	11.6	3.0
	32	10.3	53	9.3	2.7
Cellulose	8	13.1	46	13.6	3.6
	16	12.4	49	12.2	3.3
	24	11.7	54	10.3	3.0
	32	11.7	54	10.4	2.7
Necessary difference (P = .05)		2.0	6.0	1.5	

RESULTS AND DISCUSSION

Experiment No. 1

The gains and feed intakes of the mice are shown in Table 2. It is evident that there were distinct differences between feedstuffs in their effects on mouse gains as levels increased from 8 to 32 per cent of the diet. Varying degrees of growth inhibition occurred on rations other than those containing bran or cellulose, in which cases even the 32 per cent levels failed to reduce observed gains. In some cases increased feed intakes were observed as energy levels declined (corn cobs, cellulose and possibly bran). There were no differences associated with the wheat and oatmeal basals; hence all values in the table represent averages of the two basal rations.

Covariance analysis revealed a highly significant correlation between feed intakes and gains ($r = 0.64$, 111 D.F.); hence the gains adjusted for differences in dry matter intakes[1] are also shown in Table 2. It is now apparent that wheat straw, oat hulls, corn cobs and cellulose resulted in reduced growth, relative to feed intake, at or below the 24 per cent level. Alfalfa and beet pulp did not depress gains until more than 24 per cent was added and the depression obtained, although statistically different from the 8 per cent level, was not, in reality, large. Increasing the level of bran to 32 per cent resulted in no reduction in gains. These observations suggest that compensatory increases in feed intake occurred with increasing levels of certain fibrous feeds but not with others.

Calculation of the digestibility coefficients for energy yielded the following values: wheat basal 92; oat meal basal 86; bran 42; wheat straw 0; alfalfa 37; oat hulls 10; beet pulp 41; corn cobs 14, and cellulose 0 per cent. Some associative effects appeared to exist as the digestibility of the basal component (as averages of the two basals) was 89.0-89.5 per cent for cellulose, bran and wheat straw; 85.8-86.6 per cent for beet pulp, alfalfa and oat hulls, and 84.2 per cent for corn cobs. With correlation coefficients ranging from −0.83 to −0.97 for the relationship between per cent digestibility and bulk level it seems reasonable to assume that the coefficients for 'bulk' digestibility are reliable and that the associative effects noted above are real. It can also be assumed that the maximum associative effect was achieved at or below the 8 per cent minimum level of bulk in the diet since the correlation coefficients indicate a high degree of linearity beyond the 8 per cent level.

The digestible energy contents are shown in Table 2 for the various rations and it is noted that the values for the 32 per cent levels varied from 3.3 to 2.7 digestible Calories per gram. This represents a rather large variation in energy value and may account for some of the variations in gains obtained. Statistical appraisal of the weight gains, the digestible energy intakes and their interrelationships showed that about 65 per cent of the variation in gains, comparing the different bulk sources, could be accounted for by differences in digestible calorie intakes. About 95 per cent of the variation in weight gains between levels, disregarding sources, could be accounted for likewise. However, significant differences were found in the interaction between bulk sources and levels, meaning that the bulk sources differed in their effects on the animals' ability or desire to consume feed.

Experiment No. 2

The results of this test are summarized in Table 3 although the figures pertaining to alfalfa were omitted because of evidence of feed sorting.

The gains and feed intakes in this study, with rations designed to be nutritionally adequate with respect to protein, minerals and vitamins, revealed marked differences, within approximately isocaloric groups, between bulk additives. For instance, mice failed to survive on wheat straw-supplemented rations containing 2.2-2.4 digestible Cal./gm.; did poorly on the

[1]Adjusted by the formula $Y_{adj.\ gain} = Y_{obs.\ gain} - 0.2306\ X_{obs.\ feed} + 11.027$.

TABLE 3. — GROWTH AND FEED INTAKE RESULTS FROM EXPERIMENT NO. 2

Energy diluent	Level of diluent in ration	Digestible Cal./gm. of D.M.	Observed gains	Feed intakes	Gains adjusted for feed intake differences
	%	Cal.	gm.	gm.	gm.
Wheat bran	14	3.4	12.2	48	11.6
	25	3.2	12.8	53	11.2
	36	3.0	10.5	42	11.0
	46	2.9	12.1	46	11.8
	57	2.7	7.8	41	8.4
	68	2.5	9.1	43	9.5
Wheat straw	9	3.3	11.9	47	11.4
	14	3.1	10.6	46	10.4
	21	2.9	8.6	43	8.9
	27	2.6	3.4	40	6.1
	33	2.4	0.8	31	3.4
	39	2.2	0	0	0
Oat hulls	9	3.3	13.7	50	12.6
	15	3.1	11.2	53	9.6
	22	2.9	12.3	56	10.2
	29	2.7	12.2	56	10.0
	36	2.5	10.6	60	7.8
	43	2.3	8.6	60	5.8
Beet pulp	9	3.3	13.2	48	12.5
	16	3.1	12.6	47	12.1
	23	2.9	11.7	51	10.5
	30	2.7	8.9	43	9.2
	38	2.4	3.5	29	6.4
	45	2.2	2.2	24	6.1
Corn cobs]	6	3.4	11.6	49	10.9
	11	3.2	13.5	52	12.3
	16	3.1	10.4	49	9.7
	21	2.9	9.9	49	9.2
	26	2.7	7.4	45	6.5
	31	2.5	7.1	44	7.2
Cellulose	7	3.4	12.9	48	12.3
	13	3.2	9.8	41	10.6
	18	3.0	12.4	49	11.7
	24	2.8	8.4	45	8.2
	29	2.6	9.3	51	8.0
	34	2.4	4.9	42	5.4
Necessary difference (P = .05)	—	—	3.5	10	3.0
Standard error of the mean			2.5	6.8	2.2

corresponding beet pulp and cellulose rations but gained at about 70 per cent of normal rate on bran and oat hull rations. Other data involving the use of flavours* indicate that palatability was not a major factor in these findings and the statistical adjustment of gains in accordance with feed intake differences ($r = 0.51$, 108 D.F.; Table 3) suggests that some factor other than weight of feed eaten or nutritional deficiencies is involved.

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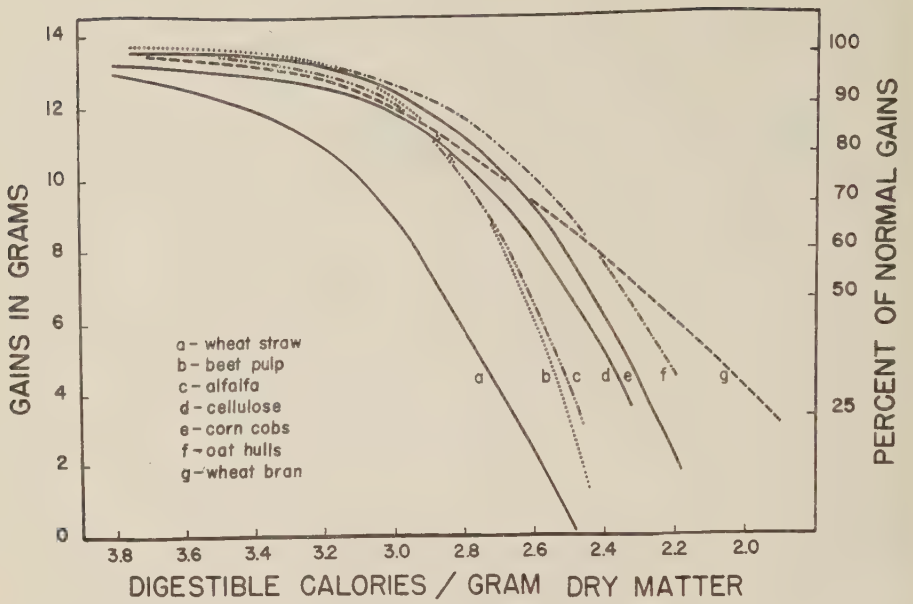

FIGURE 1. Relationships between weight gains and digestible energy contents of diets.

Although it is obvious that digestible energy per unit of feed dry matter was limiting in some cases, this factor alone was not responsible for the differences observed between feeds. A highly significant correlation ($r = 0.73$) was found between gains and energy (Calories) digested but, even after statistical adjustment of gains for differences in energy intake, there were large differences ($P = <.01$) between bulk sources and in the interactions between bulk sources and levels of digestible energy. This appeared to be due to the inability of animals fed the higher levels of wheat straw, beet pulp and cellulose to consume as many digestible calories as those fed diets containing other bulks at similar energy levels in the diets.

The general relationships between animal performance and digestible energy contents of the rations are shown in Figure 1, which includes data from both experiments. From these curves it is evident that in order to regulate animal performance by energy restriction, consideration would have to be given to the kind of ration diluent used. For instance, a ration designed to produce 70 per cent of normal gains[1] would require about 2.6 dig. Cal./gm. if bran were the diluent but this level might give very poor results with alfalfa and beet pulp and would involve some mortality in the case of wheat straw.

Further insight into various factors which may be involved is provided by Figure 2 which depicts certain characteristics of rations which permitted about 60 per cent of normal gain. From these values it is apparent that animal performance was not determined primarily by level (per cent by weight) of fibrous diluent in the ration, by apparent volume in the stomach,

[1]'Normal gains' refers to 13.0-13.5 gm. gain in weight over this period as typically achieved in our laboratory with this strain of mice fed nutritionally adequate diets.

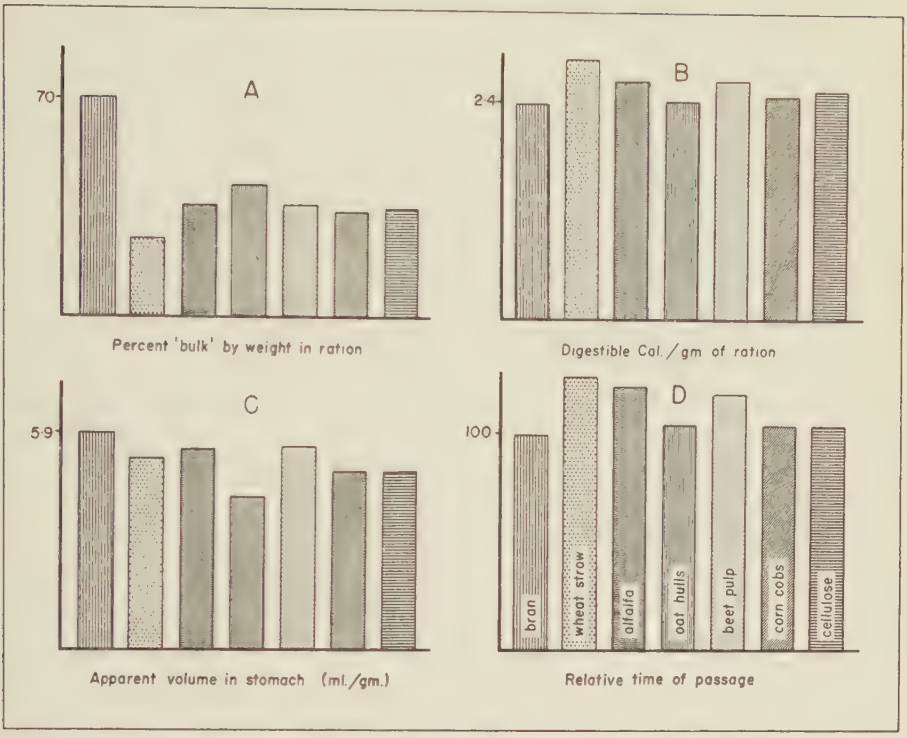

FIGURE 2. Characteristics of rations which permitted 60 per cent of normal growth showing variations in (A) percentage of 'bulk' component in the diet, (B) digestible energy content per gram of ration, (C) apparent volume in stomach and (D) relative passage time through the gastrointestinal tract.

nor by digestible energy content of the ration. It was possible, however, to calculate *relative* rates of passage of ingesta through the gastrointestinal tract. On this basis (Figure 2, section D) rations containing wheat straw, alfalfa and beet pulp were processed more slowly than when other 'bulks' were involved. Bran passed through most rapidly at any given level of animal performance. It is recalled that there was no evidence from the digestibility studies that digestion coefficients of the fibrous component were affected by *level* of diluent included so rate of passage estimates apparently were not invalidated by limitation of digestive enzymes as rates increased.

In Figure 3, Section F, it can be seen that wheat straw, alfalfa and beet pulp, the feeds having the slowest rates of passage, had the smallest apparent volumes when wet, were less capable of swelling in water and presumably occupied less space per unit weight in the stomach. This behaviour would tend to minimize their effects on stomach fill and on appetite but, despite the fact that these feeds were digested to the extent of 0 to 41 per cent, both wheat straw and alfalfa, as well as corn cobs and cellulose, (Figure 3, section H) tended to retain their physical forms or volumes throughout digestion. Hence the volume of the indigestible residue in the lower bowel, according to these *in vitro* measurements, may

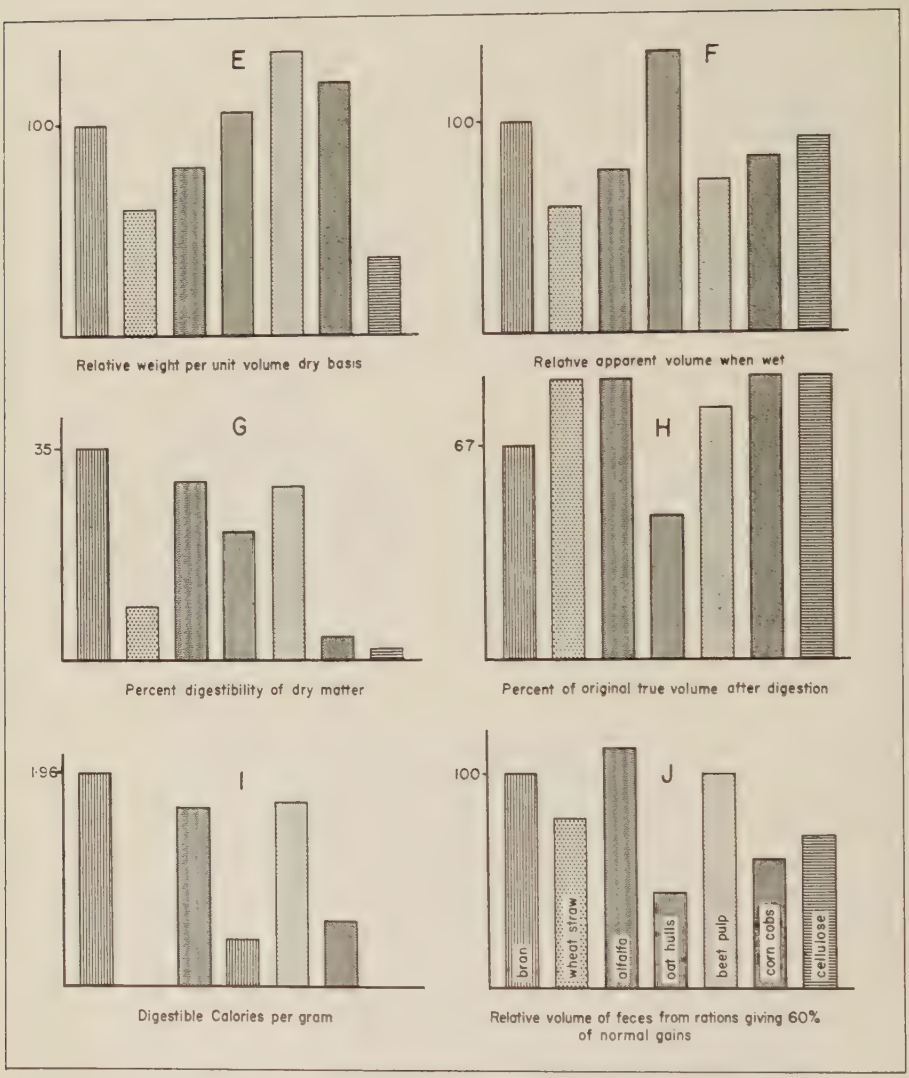

FIGURE 3. Characteristics of bulk ingredients showing variations in (E) density or relative weight per unit volume dry, (F) relative volume wet, (G) digestibility of dry matter, (H) effect of digestion on ingesta volume, (I) digestible energy per gram and (J) relative fecal volumes from rations that permitted 60 per cent of normal gains.

have been an important factor influencing the results obtained. Application of these results to the feed and feces data for rations permitting 60 per cent of normal gains (Figure 3, section J) indicated marked differences in fecal volumes, and no general similarity seems to exist between the volume characteristics in the stomach and those in the feces or lower bowel.

In view of the interrelationships between volume in the stomach, volume of the digestive residue and rate of gain, these three factors have been plotted in 3-dimensions in Figure 4 from the results of Experiment 2.

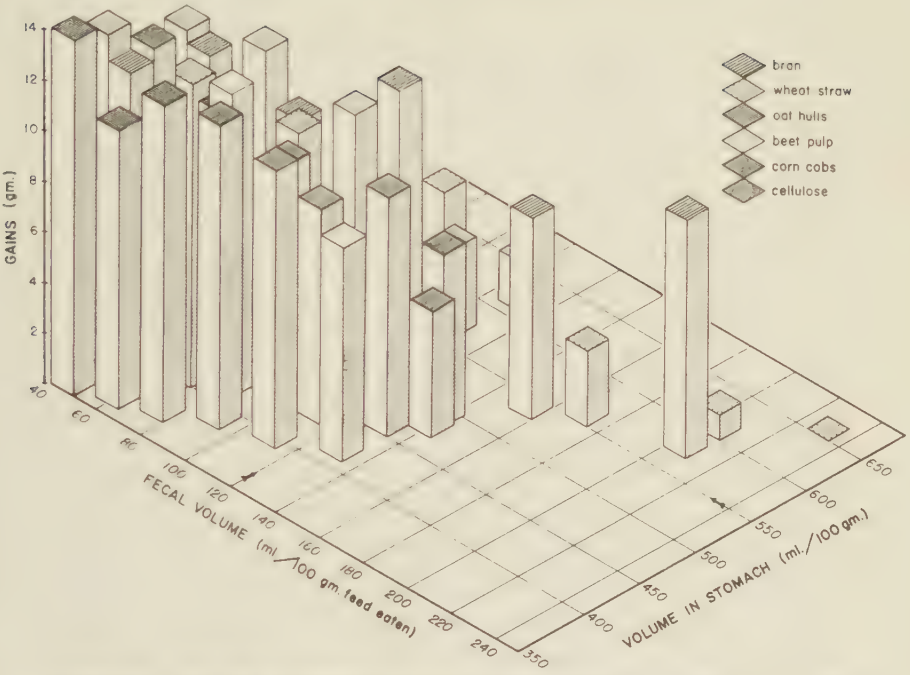

FIGURE 4. Graphical interrelationships between volume of food in the stomach, fecal volume and rate of gain, according to the type of bulk diluent incorporated in the ration.

From this diagram it appears that, in general, maximum gains were obtained when the apparent volume in the stomach did not exceed 550 ml./100 gm. feed dry matter and when the fecal volume from 100-gm. feed did not exceed about 120 ml. The single outstanding exception to these limits is wheat bran, which permitted good growth at a fecal volume of 200 and a stomach volume of 550 ml./100 gm. dry matter fed.

Rose (19) and Fantus and Frankl (11) have reported on the effects of bran and its mode of action and noted that the feces resulting therefrom contain more water and more fatty acids than in the absence of bran, thus suggesting increased microbial action in the large intestine and cecum. While there appear to be no reports of a similar nature concerning the other diluents used here, it is possible that bran possesses some properties not common to the other feeds in this respect.

These experiments have provided evidence that widely varying responses can be obtained from isocaloric diets, which are nutritionally adequate in the usual sense, depending on the nature of the fibrous or bulky ingredients used. No basic formula or criterion is offered as a predictor of the response obtainable from the bulk component but our results indicate that such attributes as dry density, digestibility of dry matter or energy, crude fibre content or palatability are not reliable indices by themselves. It is believed that factors, physical or chemical, related to water-holding capacity in the various stages of digestion are worthy of further investigation, since these factors could influence stomach-emptying time, peristaltic

rates and perhaps appetite. Digestible or metabolizable energy contents of diets will, in many cases, remain unsatisfactory indicators of animal performance until more is known about the factors affecting intake levels.

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INGREDIENT AND PROCESSING INTERRELATIONSHIPS IN SWINE FEEDS

I. EFFECTS OF ANTIBIOTICS, PROTEIN SOURCE AND WHEAT BRAN ON THE RESPONSES TO PELLETED FEED

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ABSTRACT

A swine feeding trial, of 2 x 2 x 2 x 2 factorial design, involving 64 pigs (32 gilts and 32 barrows) weighing initially 50 ± 2 pounds and fed to a final weight of 110 ± 2 pounds was carried out. The dietary variables were meal vs. pellets, 0 vs. 10 per cent wheat bran, mixed animal-plant vs. all-plant origin protein supplement and 0 vs. 33 p.p.m. of an antibiotic mixture (penicillin, streptomycin and chlortetracycline). Weight gains and feed intakes were recorded bi-weekly and a Cr_2O_3-marker digestion trial was imposed on 32 pigs during the feeding test.

The results revealed distinct interrelationships among all four experimental variables that prevailed through to the highest order statistical interaction. Consequently discussion in this paper was restricted to those factors affecting the responses to pelleting.

On the whole there was no advantage due to pelleting. However, in the absence of bran and antibiotics, and particularly when no animal protein was involved, pigs fed pelleted feed gained faster and had better feed efficiency. Pelleting was found to increase dry matter and energy digestibility when no bran or antibiotics were included in the diet. Conversely, the inclusion of either bran or antibiotics was as effective as pelleting. It is postulated that bran and antibiotics were effective by reason of their effects on the physical nature of the ingesta and on the microbial population of the gastrointestinal tract.

INTRODUCTION

The limited information available indicates that pelleting of swine rations results in improved growth responses compared to meal rations. The growth-stimulating effect has been attributed to increased feed density, particularly when bulky, high-swelling feeds were involved and in some instances to improved palatability (10).

A direct association between crude fibre content and the efficacy of pelleting was demonstrated by Bohman *et al.* (4) and Hoefer *et al.* (10). As fibre level in the diet increased the meal rations produced progressively poorer responses whereas relatively little effect resulted when the corresponding rations were pelleted. The diverging responses became especially marked when the stomach capacity limited the amount of bulky meal that could be consumed.

Research with chicks (1, 2) led to the postulation that some chemical or physical change in the ration may be incurred by the heat and pressure developed in the pelleting process. It was shown that pelleted, re-ground rations produced superior chick responses compared to identical non-pelleted rations.

This report presents the results of one phase of a factorial experiment designed to assess the interrelationships between pelleting and such dietary components as wheat bran, antibiotics and animal versus plant protein supplements.

[1]Formerly graduate student, Department of Animal Husbandry.
[2]Professor and Head, Department of Animal Husbandry.
[3]Associate Professor of Animal Husbandry.

TABLE 1. — DESIGN OF THE SWINE FEEDING EXPERIMENT
(FOUR INDIVIDUALLY-FED PIGS PER RATION; 2 ♂, 2 ♀)

Wheat bran (%)	Antibiotic level (p.p.m.)	Meal		Pellets	
		Mixed protein	All-plant protein	Mixed protein	All-plant protein
		Ration No.			
0	0	1	5	9	13
	33	2	6	10	14
10	0	3	7	11	15
	33	4	8	12	16

TABLE 2. — COMPOSITION OF SWINE GROWER RATIONS

Ingredient (lb.)	Mixed protein		All-plant protein	
	Nil	Bran	Nil	Bran
	Ration 1[1,2]	Ration 3	Ration 5	Ration 7
Wheat	44.1	39.3	43.8	39.3
Barley	44.1	39.3	43.8	39.3
Linseed oil meal	6.5	6.3	6.9	6.3
Meat meal	3.3	3.1	—	—
Soybean oil meal	—	—	3.5	3.2
Wheat bran	—	10.0	—	10.0
Salt (iodized)	.50	.50	.50	.50
Ground limestone	1.00	1.20	1.24	1.50
Dicalcium phosphate	.50	—	.90	.50
Vitamins A and D_2 (1500A, 300D/gm.)	.148	.148	.148	.148
$ZnSO_4.7H_2O$	.02	02	.02	.02
Vitamin B_{12} supplement	—	—	.11	.11
Total	100.0	100.0	100.0	100.0

[1]Rations 2, 4, 6 and 8 corresponded to rations 1, 3, 5 and 7 respectively plus the addition of 0.10 lb. of antibiotic mixture.

[2]Rations 1 to 8 inclusive were in the meal form and 9 to 16 were similar to 1 to 8 respectively in the pellet form.

MATERIALS AND METHODS

Experimental Design and Objectives

The general plan of the experiment is indicated in Table 1 from which it is seen that the variables under test were 0 versus 10 per cent wheat bran, all-plant versus mixed (animal-plant) origin protein, meal versus pellets (5/16 inch), zero versus 33 p.p.m. antibiotics and, in factorial design, all possible combinations of these treatments. Purebred Yorkshire pigs weighing initially 50 ± 2 pounds and fed to a final weight of 110 ± 2 pounds were used. Thirty-two gilts and thirty-two barrows were randomly allotted to individual feeding stalls and to rations. The pigs were accommodated in pens of 4 and were allowed into their respective stalls for feeding twice daily. Liveweight gains and feed intake records were taken bi-weekly throughout the test.

Rations

The formulas of the experimental rations are shown in Table 2. The energy level was held constant at 75 per cent T.D.N. based on available published information. The protein level was established at 17.7 per cent on the basis of a protein:energy ratio of 53 mg. crude protein per Kilocalorie of digestible energy and 4.45 digestible Kilocalories[1] per gram of T.D.N. Minerals and vitamins were provided in accordance with the N.R.C. nutrient requirements (14). Vitamins A and D_2 were supplied as a dry mixture containing stabilized vitamin A[2]. Zinc sulphate was included to provide 80 p.p.m. of zinc as a preventive measure against the possible development of parakeratosis.

The mixed animal-plant protein supplement consisted of one-third meat meal and two-thirds linseed oil meal (expeller). The all-plant protein supplement was composed of one-third soybean oilmeal and two-thirds linseed oil meal.

A vitamin B_{12} supplement[3] was added to the all-plant rations to provide 6.6 μgm. vitamin B_{12} per therm of digestible energy. The antibiotic mixture consisted of equal parts by weight of Prostrep[4] and Aurofac-10[5] and supplied a total antibiotic level of approximately 33 p.p.m. of ration.

Digestibility Studies

About mid-way in the feeding trial one-half of the pigs had Cr_2O_3 incorporated into their rations in order to permit estimation of digestion coefficients by a chemical index method. Because of the tendency for Cr_2O_3 to settle out of the feed (12, 13, 17) the marker was pre-mixed with enough corn oil to provide 0.4 per cent added oil in the diet. This thick paste was diluted with enough petroleum solvent (Skelly F) to produce a creamy consistency following which it was mixed with the feed in an auger-type feed mixer. The marker-containing feed was then spread in a thin layer to remove the solvent by evaporation. This procedure was also used to incorporate Cr_2O_3 into pelleted rations. Some breakage of pellets occurred as a result.

The procedures followed during the collection period were those reported by Clawson (7), Horvath (11) and Moore (12) with minor modifications. Following a 3-day preliminary period, representative freshly deposited fecal samples were collected three times daily (9.00 a.m., 1.00, and 4.30 p.m.) for 3 consecutive days. The three daily samples from each pig were composited in a polyethylene bag, mixed with 50 millilitres of a 4 per cent boric acid solution plus 1 millilitre toluene and stored in a refrigerator. Finally, the 3 days' collections were pooled, water was added as necessary to produce a thick slurry and the material was mixed thoroughly in a large Waring blender. Samples for chemical analysis were obtained

[1]Crampton, E. W. *Personal communication.* The relationship was revised, after this experiment was initiated, to 4.5 dig. Cal./gm, T.D.N. (The caloric value of T.D.N. E. W. Crampton, L. E. Lloyd and V. G. MacKay. J. Animal Sci. 16:541-545, 1957).

[2]Courtesy N. D. Hogg, Ltd., Toronto. Each gram of supplement contained 1500 I.U. of Vitamin A and 300 I.U. of Vitamin D_2.

[3]Courtesy Merck & Co., Montreal. Each pound of supplement contained 9 mg. of vitamin B_{12}.

[4]Courtesy of Merck & Co., Montreal. Prostrep contains 5 gm. of procaine G. penicillin and 15 gm. of streptomycin per pound.

[5]Courtesy N. D. Hogg Ltd., Toronto. Aurofac-10 contains 10 gm. chlortetracycline per pound.

TABLE 3.— EFFECTS OF ANTIBIOTICS, PROTEIN SOURCE AND WHEAT BRAN ON GAINS AND FEED UTILIZATION OF GROWING SWINE

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Meal	Pellets	Meal	Pellets	Meal	Pellets	Meal	Pellets	Meal	Pellets
All treatments	32	1.16[1]	1.19	3.29	3.33	1.17	1.18	4.77	4.89	.39	.39
Antibiotic treatment											
Nil	16	1.10	1.14	3.21	3.26	1.13	1.16	4.56	4.72	.38	.37
Antibiotics	16	1.22	1.21	3.37	3.40	1.20	1.18	4.99	5.05	.41	.41
Protein source											
Mixed protein	16	1.19	1.20	3.40	3.34	1.16	1.19	4.95	4.92	.40	.39
Plant protein	16	1.16	1.19	3.18	3.32	1.20	1.19	4.60	4.86	.38	.39
Bran treatment											
Nil	16	1.14	1.15	3.20	3.22	1.18	1.18	4.60	4.70	.37	.37
Bran	16	1.19	1.22	3.37	3.45	1.17	1.17	4.95	5.08	.42	.41
Antibiotics x bran interaction											
No antibiotics, no bran	8	1.03	1.16*	3.07	3.18	1.11	1.20*	4.24	4.56	.35	.35
+ bran	8	1.17	1.20	3.35	3.35	1.16	1.19	4.87	4.88	.41	.39
Antibiotics, no bran	8	1.24	1.14	3.34	3.26	1.23	1.16	4.96	4.84	.39	.38
+ bran	8	1.20	1.25	3.40	3.54	1.17	1.17	5.02	5.27	.43	.44
Antibiotics x protein interaction											
No antibiotics, mixed protein	8	1.14	1.18	3.41	3.24	1.11	1.20**	4.98	4.69	.41**	.36
plant protein	8	1.06	1.18*	3.01	3.29*	1.16	1.19	4.13	4.76**	.35	.38*
Antibiotics, mixed protein	8	1.25	1.22	3.39	3.44	1.22	1.18	4.93	5.15	.39	.41
plant protein	8	1.19	1.17	3.35	3.39	1.18	1.15	5.06	4.96	.42	.41

TABLE 3. — EFFECTS OF ANTIBIOTICS, PROTEIN SOURCE AND WHEAT BRAN ON GAINS AND FEED UTILIZATION OF GROWING SWINE (Cont'd)

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Meal	Pellets	Meal	Pellets	Meal	Pellets	Meal	Pellets	Meal	Pellets
Protein x bran interaction											
Mixed protein, no bran	8	1.18	1.16	3.34	3.25	1.17	1.18	4.87	4.81	.38	.37
+ bran	8	1.21	1.24	3.45	3.43	1.16	1.20	5.04	5.03	.42	.40
Plant protein, no bran	8	1.09	1.15	3.07	3.19	1.17	1.19	4.34	4.59	.35	.37
+ bran	8	1.16	1.20	3.29	3.46	1.17	1.15	4.85	5.13	.42	.42
Antibiotics x protein x bran interaction											
No antibiotics, no bran, mixed protein	4	1.10	1.12	3.38	3.21	1.08	1.15	4.87	4.63	.40	.36
plant protein	4	0.96	1.20*	2.76	3.15*	1.15	1.26*	3.62	4.49**	.30	.35*
+ bran, mixed protein	4	1.18	1.24	3.43	3.28	1.14	1.25*	5.10	4.75	.42*	.36
plant protein	4	1.17	1.15	3.26	3.42	1.19	1.11	4.64	5.02	.39	.41
Antibiotics, no bran, mixed protein	4	1.26	1.19	3.30	3.30	1.26	1.19	4.87	4.99	.37	.38
plant protein	4	1.22	1.09	3.38	3.22	1.20	1.12	5.06	4.68	.41	.38
+ bran, mixed protein	4	1.24	1.25	3.48	3.58	1.18	1.16	4.98	5.30	.42	.45
plant protein	4	1.16	1.25	3.32	3.51	1.16	1.18	5.07	5.24	.44	.43

[1]See Table 5 for necessary differences.
*Differences significant at P = .05
**Differences significant at P = .01

by filling, from each slurry, 12 half-ounce portion paper cups. These, with the exception of samples used immediately for dry matter determinations, were quick-frozen and stored in a deep freeze.

Chemical and Statistical Analyses

Feed and fecal samples were analysed in duplicate for gross energy, crude protein and Cr_2O_3. Gross energy was determined in a Parr Oxygen bomb calorimeter equipped with an automatic temperature recorder. The official macro-Kjeldahl method (3) was used for crude protein analysis, modified by the use of the receiving acid and indicator developed by Sher (17). Chromic oxide was determined by the method of Bolin *et al.* (5) as modified by Crampton[1].

All results were subjected to analysis of variance, several to covariance analysis and the differences required for significance were determined by the methods of Snedecor (18).

RESULTS AND DISCUSSION

Data pertaining to the responses of pigs fed meal or pellets under the various experimental conditions are shown in Table 3. There were no differences in the over-all effects between meal and pellet rations; however it was found that each one of the variables under study influenced the response to pelleting of the ration. Thus favourable responses to pelleting as found by others (4, 9, 10, 19) appear, from this experiment, to be dependent on several dietary characteristics or constituents.

Improved performance due to pelleting was shown by those pigs fed pelleted rations free of antibiotics and at the same time supplemented with plant protein. The pigs ate more and gained faster than their counterparts fed meal rations of the same formulas. Likewise, pigs fed antibiotic-free and bran-free diets performed better with pelleted feed. These observations indicate that while pelleting may enable an animal to consume more of certain types of bulky feeds than would be possible in meal form, the inclusion of bran or antibiotics may produce a similar net result, presumably by some other means. The responses to bran, antibiotics and protein source were not additive in this experiment. This is apparent from the final comparisons in Table 3 which record an average daily gain of 1.25 pounds for a pelleted ration containing bran, antibiotics and mixed protein, and a gain of 0.96 pounds/day on a meal ration devoid of bran, antibiotics and animal protein. However, there were several rates of gain in excess of 1.2 pounds/day and involving rations either unpelleted or lacking one of the above-mentioned ingredients.

Covariance analyses indicated that daily gains and feed intakes were significantly correlated. Therefore, adjusted daily gains were calculated for equal daily feed intakes (Table 3). This statistical treatment revealed some advantages from pelleting that were not apparent previously such as occurred with the pelleting of antibiotic-free, mixed protein-supplemented rations. It also indicated that increased feed intake did not always fully

[1]The original procedure of Bolin *et al.* was modified by use of an oxidizing reagent containing 5 gm. of sodium molybdate in 1 litre of water, with 1 litre of perchloric acid (70-72%) added to this solution. Two 10-ml. portions of this reagent were used for digestion. The final solution was filtered through medium paper, the first 25 ml. being discarded, prior to reading in the colorimeter.

TABLE 4. — EFFECT OF ANTIBIOTICS, MIXED OR PLANT PROTEIN, AND WHEAT BRAN ON SWINE DIGESTIBILITY COEFFICIENTS WITH MEAL OR PELLETS

Treatment	n	Digestibility coefficients (%)					
		Dry matter		Gross energy		Crude protein	
		Meal	Pellets	Meal	Pellets	Meal	Pellets
All treatments	16	73.6[1]	74.2	73.9	74.8	74.0	72.4
Bran treatment							
Nil	8	73.2	74.4*	73.4	75.0	71.8	71.4
Bran	8	74.0	74.1	74.3	74.7	76.3*	73.4
Antibiotic treatment							
Nil	8	72.2	73.9*	72.5	74.3*	73.5	71.1
Antibiotics	8	74.9	74.6	75.3	75.4	74.6	73.6
Protein source x antibiotic interaction							
Mixed protein, no antibiotics	4	74.3	74.2	74.8	74.3	75.2*	69.9
+ antibiotics	4	73.7	75.2	73.8	76.0	72.3	74.4
Plant protein, no antibiotics	4	70.2	73.6**	70.1	74.3**	71.9	72.4
+ antibiotics	4	76.1*	74.0	76.7	74.7	76.8*	72.9
Bran x antibiotic interaction							
No bran, no antibiotics	4	71.1	74.4**	71.3	74.7*	71.6	70.5
+ antibiotics	4	75.2	74.5	75.6	75.3	71.9	72.3
Bran, no antibiotics	4	73.4	73.4	73.6	73.9	75.5	71.8
+ antibiotics	4	74.6	74.8	75.0	75.5	77.2	75.0

[1]See Table 5 for necessary differences.
*Differences significant at P = .05
**Differences significant at P = .01

explain the benefits of pelleting. Substantiating this finding, the data in Table 4 show that the growth-stimulating effect of pelleting was due, in part at least, to improved digestibility of dry matter and energy, which in turn may have reflected chemical changes resulting from the pelleting process (1, 2). These findings appear to be particularly useful in explaining the effects of pelleting rations containing plant protein supplements. Although it has been shown that increased rate of passage of ingesta through the gastrointestinal tract may result from the enhanced consumption (6), and that plant protein supplements contain more crude fibre than corresponding animal products (9, 15), the data from this experiment indicate that palatability and feed intake played minor roles. It is apparent (Table 4) that the pelleting process improved dry matter digestibility to a highly significant degree when neither bran nor antibiotics were included in the ration. It is perhaps equally important to observe that the inclusion of either bran or antibiotics was as effective as pelleting in improving growth and feed efficiency of growing swine. Contrary to the favourable effects of pelleting on digestibility of dry matter and energy, any advantages in digestibility of crude protein were in favour of meal rations. It will be noted that rations containing bran, or those containing mixed protein *without* antibiotics or plant protein *with* antibiotics exhibited significantly lower digestibility coefficients when fed as pellets. No explanation is offered for these apparently unrelated ingredient-pelleting interrelationships nor is it known to what extent, if any, these differences in protein digestibility may have affected gains of the pigs. A study of the amino acid adequacy, based on published data, revealed no important differences between any of the diets. All rations were potentially deficient in lysine, methionine and histidine but the provision of 17.7 per cent protein, compared to requirements of 16 per cent or less (14), may have nullified much of the potential amino acid deficiency problem.

On the basis of the findings of this experiment it may be concluded that, whereas pelleting has been shown by others to improve palatability and feed intakes by decreasing dustiness and increasing feed density, the potential advantages of pelleting are subject to variations in ration formulation. The results confirm previous findings of others to the effect that pelleting may change chemical composition of the diet, since increased dry matter and energy digestibility coefficients and decreased protein digestibility coefficients were obtained following the pelleting of some of the rations. It is suggested that the failure of pelleting to effect a response when the rations contained either 10 per cent wheat bran or 33 p.p.m. of an antibiotic mixture was due to these ingredients improving appetites, and sometimes digestibility, through modified physical nature of the ingesta and altered microbial activity in the gastrointestinal tract. In view of the interdependence found between antibiotics, bran and pelleting and the non-additive effects evident from the results of this experiment, it would be of interest to re-examine the interrelationships under strictly *ad libitum* feeding conditions. It is possible that twice-daily feeding may have imposed sufficient restrictions on feed consumption to prevent the full manifestation of factors bearing on appetite.

TABLE 5. — NECESSARY DIFFERENCES FOR STATISTICAL SIGNIFICANCE BETWEEN TREATMENT MEANS

Criteria measured	Number of individual values making up the mean (n)			
	32	16	8	4
Rate of gain (lb./day)	.06	.08	.12	.16
Feed intake (lb. dry matter/day)	.13* (.17)	.18 (.25)	.26 (.35)	.37 (.50)
Adjusted rate of gain (lb./day)	.04 (.05)	.05 (.07)	.07 (.10)	.10 (.14)
Energy digested (therms/day)	.19 (.26)	.27 (.36)	.38 (.51)	.54 (.73)
Protein digested (lb./day)	.02 (.02)	.02 (.03)	.03 (.04)	.05 (.06)
Dry matter digestibility (%)		.80 (1.21)	1.13 (1.71)	1.60 (2.42)
Energy digestibility (%)		1.19 (1.80)	1.68 (2.55)	2.38 (3.61)
Protein digestibility (%)		1.92 (2.90)	2.71 (4.10)	3.84 (5.81)

*Statistical significance at P = .05 and, in parentheses, at P = .01

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INGREDIENT AND PROCESSING INTERRELATIONSHIPS IN SWINE FEEDS

II. EFFECTS OF ANTIBIOTICS, PROTEIN SOURCE AND PELLETING ON THE RESPONSES TO THE INCLUSION OF WHEAT BRAN

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ABSTRACT

This is the second in a series of reports on the growth, feed intake and digestibility responses of growing swine (50 to 110 pounds) involved in a 2 x 2 x 2 x 2 factorial test of the effects of wheat bran, pelleting, antibiotics and type of protein in the ration. Discussion in this paper was restricted to those factors affecting the responses to the inclusion of wheat bran.

With approximately isocaloric diets the inclusion of 10 per cent bran resulted in a general increase of 6 per cent in feed intake ($P = <.01$) and 8 per cent in digestibility of protein. The greatest effects were obtained with antibiotic-free, animal protein-free, meal-type rations in which the inclusion of bran resulted in 18 per cent more feed and 28 per cent more digestible energy being consumed.

The effect of bran on energy digestibility was small relative to its effect on protein. It is postulated that differences in the rates and site of absorption of starch and protein components may be related to the efficacy of bran in the digestive tract.

The similarity observed between the effects of bran and antibiotics is discussed in relation to possible deficiencies of B-vitamins and amino acids.

INTRODUCTION

The effects of including bran in non-ruminant diets have been studied with humans (7, 8, 11), swine (6, 12), and laboratory animals (1). The growth-stimulating action which resulted in some studies was associated with increased rate of passage of the ingesta. The laxative nature of wheat bran has been attributed to various factors, foremost among which is the ability of bran to absorb and hold large quantities of water at all stages of digestion. In this respect peristaltic activity appears to be stimulated by increased ingesta volume. Sheehy (12) regarded bran as a valuable feed ingredient for the establishment of optimum mechanical conditions in the digestive tract by its favourable influence on the activity of the lower gut and by promoting more rapid digestion of the diet in the stomach. The flaky nature of bran was believed to produce a physical condition of the ingesta more favourable to enzymatic action.

Other workers (8) have suggested that bran residues stimulate bacterial action in the lower gut with a resultant increase in production of volatile fatty acids and gases. Both products are believed to stimulate peristalsis and hence facilitate fecal elimination. Cooper and Tyler (6) observed extensive gas production as a result of feeding rations containing bran to swine.

This report is the second of a series dealing with the results of a factorial experiment involving growing pigs fed rations designed to evaluate the effects and interrelationships of meal versus pellets, 0 versus 33 p.p.m. mixed antibiotics, 0 versus 10 per cent wheat bran and plant protein versus mixed animal-plant protein supplements. This report concerns the factors found to influence the efficacy of bran as an ingredient in swine rations.

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TABLE 1. — EFFECTS OF ANTIBIOTICS, PELLETING AND ORIGIN OF PROTEIN ON RESPONSES OF GROWING SWINE TO THE INCLUSION OF 0 OR 10 PER CENT WHEAT BRAN IN THE RATION

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Nil	Bran	Nil	Bran	Nil	Bran	Nil	Bran	Nil	Bran
All treatments	32	1.14[1]	1.20*	3.21	3.41**	1.17	1.16	4.65	5.01**	.367	.415**
Antibiotics											
Nil	16	1.10	1.18*	3.12	3.35*	1.16	1.17	4.40	4.88**	.351	.395**
Antibiotics	16	1.19	1.22	3.30	3.47	1.19	1.16	4.90	5.15	.383	.435**
Meal versus pellets											
Meal	16	1.14	1.19	3.20	3.37	1.18	1.17	4.60	4.95*	.367	.418**
Pellets	16	1.15	1.22	3.22	3.45	1.18	1.17	4.70	5.08**	.368	.412**
Protein supplements											
Mixed protein	16	1.17	1.23	3.30	3.44	1.17	1.18	4.84	5.03	.376	.412**
Plant protein	16	1.12	1.18	3.13	3.38**	1.18	1.16	4.46	4.99**	.359	.418**
Antibiotic x pelleting interactions with bran											
No antibiotics, meal	8	1.03	1.17*	3.07	3.35*	1.11	1.16	4.24	4.87**	.349	.405**
pellets	8	1.16	1.20	3.18	3.35	1.20	1.19	4.56	4.88	.354	.385
Antibiotics, meal	8	1.24	1.20	3.34	3.40	1.23	1.17	4.96	5.02	.385	.431**
pellets	8	1.14	1.25	3.26	3.54*	1.16	1.17	4.84	5.27*	.381	.439**
Antibiotic x protein supplement interactions with bran											
No antibiotics, mixed protein	8	1.11	1.21	3.29	3.36	1.12	1.19*	4.75	4.92	.379	.391
plant protein	8	1.08	1.16	2.96	3.34**	1.20	1.15	4.06	4.83**	.324	.399**
Antibiotics, mixed protein	8	1.22	1.24	3.30	3.53	1.22	1.16	4.93	5.14	.373	.433**
plant protein	8	1.16	1.20	3.30	3.41	1.16	1.17	4.87	5.15	.394	.438**

TABLE 1. — EFFECTS OF ANTIBIOTICS, PELLETING AND ORIGIN OF PROTEIN ON RESPONSES OF GROWING SWINE TO THE INCLUSION OF 0 OR 10 PER CENT WHEAT BRAN IN THE RATION—(Continued)

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Nil	Bran	Nil	Bran	Nil	Bran	Nil	Bran	Nil	Bran
Pelleting x protein supplement interaction with bran											
Meal, mixed protein	8	1.18	1.21	3.34	3.45	1.17	1.16	4.87	5.04	.381	.420*
plant protein	8	1.09	1.16	3.07	3.29	1.17	1.17	4.34	4.85*	.353	.416**
Pellets, mixed protein	8	1.16	1.24	3.25	3.43	1.18	1.20	4.81	5.03	.370	.404*
plant protein	8	1.15	1.20	3.19	3.46*	1.19	1.15	4.59	5.13	.365	.420**
Antibiotic x pelleting x protein interactions with bran											
No antibiotics											
Meal, mixed protein	4	1.10	1.18	3.38	3.43	1.08	1.14	4.87	5.10	.398	.420
plant protein	4	0.96	1.17*	2.76	3.26**	1.15	1.19	3.62	4.64**	.300	.390**
Pellets, mixed protein	4	1.12	1.24	3.21	3.28	1.15	1.25	4.63	4.75	.360	.363
plant protein	4	1.20	1.15	3.15	3.42	1.26**	1.11	4.49	5.02	.348	.408*
Antibiotics											
Meal, mixed protein	4	1.26	1.24	3.30	3.48	1.26	1.18	4.87	4.98	.365	.420*
plant protein	4	1.22	1.16	3.38	3.32	1.20	1.16	5.06	5.07	.405	.443
Pellets, mixed protein	4	1.19	1.25	3.30	3.58	1.19	1.16	4.99	5.30	.380	.445**
plant protein	4	1.09	1.25	3.22	3.51	1.12	1.18	4.68	5.24*	.383	.433*

[1]The actual differences required for significance were presented previously (9)
*Significant difference between 0 and 10 per cent bran @ P = .05
**Significant difference between 0 and 10 per cent bran @ P = .01

TABLE 2. — EFFECT OF MEAL OR PELLETS, MIXED ANTIBIOTIC, AND MIXED OR PLANT PROTEIN ON SWINE DIGESTIBILITY COEFFICIENTS WITH RATIONS CONTAINING 0 OR 10 PER CENT WHEAT BRAN

Treatment	n	Digestibility coefficient (%)					
		Dry matter		Gross energy		Crude protein	
		Nil	Bran	Nil	Bran	Nil	Bran
All treatments	16	73.8[1]	74.0	74.2	74.5	71.6	74.9**
Meal versus pellets							
Meal	8	73.2	74.0	73.4	74.3	71.8	76.3**
Pellets	8	74.4	74.1	75.0	74.7	71.4	73.4
Protein supplements							
Mixed protein	8	75.0*	73.7	75.4	74.0	72.0	73.9
Plant protein	8	72.6	74.4**	73.0	74.9*	71.2	75.8**
Antibiotics							
Nil	8	72.7	73.4	73.0	73.7	71.0	73.6
Antibiotics	8	74.8	74.7	75.4	75.2	72.1	76.1*
Antibiotics x pelleting interaction with bran							
Meal, nil	4	71.1	73.4*	71.3	73.6	71.6	75.5*
antibiotics	4	75.2	74.6	75.6	75.0	71.9	77.2*
Pellets, nil	4	74.4	73.4	74.7	73.9	70.5	71.8
antibiotics	4	74.5	74.8	75.3	75.5	72.3	75.0
Antibiotics x protein interaction with bran							
Mixed protein, nil	4	74.6	73.8	74.9	74.2	72.0	73.1
antibiotics	4	75.3*	73.6	75.9	73.9	71.9	74.7
Plant protein, nil	4	70.8	73.0*	71.1	73.3	70.1	74.1*
antibiotics	4	74.4	75.8	74.9	76.6	72.2	77.5*

[1]The actual differences required for significance were presented previously (9)
*Significant at P = .05
**Significant at P = .01

MATERIALS AND METHODS

This experiment involved 64 Yorkshire pigs (32 barrows, 32 gilts) in a feeding and digestibility study over the weight range of 50 to 110 pounds liveweight. The rations contained 17.7 per cent protein, 75 per cent Total Digestible Nutrients (T.D.N.) and the usual vitamin and mineral supplements that are recommended for pigs of this age (10). Complete details of the experiment were presented by Gorrill *et al.* (9).

RESULTS AND DISCUSSION

The results of the experiment as they pertain to the use of bran are given in Tables 1 and 2. Complex interrelationships are evident in the results and while final conclusions obviously must be drawn from the interaction effects it is of interest to examine the main effects. The general effect of the inclusion of 10 per cent bran was to increase rate of gain and the daily feed intake. It cannot be concluded, however, from this observation that the animal response represented an attempt to maintain caloric intake because, first, the rations were approximately isocaloric and, second, the increased gain indicates an actual increase in digestible calorie consumption. The latter observation is confirmed (Table 1) by the highly significant ($P = <.01$) increase in energy and protein digested per day.

While bran-supplemented diets excelled their controls in 26 out of the 27 comparisons for gains (Table 1), the advantage occurred to a statistically-significant degree only when the rations were antibiotic-free, contained no animal-origin protein and were fed as meal. The effect of bran on feed intakes also followed this pattern but the increases due to bran were more frequently significant and included some comparisons involving pelleted feeds.

Daily gains and feed intakes were significantly correlated ($r = 0.78$, 30 D.F.); consequently, adjusted daily gains were computed (Table 1). It was found that in most cases (one exception) the greater daily gains associated with bran diets were due to increased feed intakes *per se*. The single instance in which the adjusted gain for bran-free diets excelled appears to have been due largely to one animal in the control group; therefore, little importance is attached to this apparent difference between treatments.

Energy digestibility does not appear to have been influenced by the presence or absence of bran to any appreciable extent. Only in the case of the plant protein-supplemented diets was there a significant effect ($P = .05$) and, since the energy fraction includes protein, it is possible that the increased protein digestibility (Table 2) was mainly responsible for this effect. Despite the fact that bran generally did not influence energy digestibility, it was found, when digestibility and feed intakes were considered together, that bran did result in marked increases in amounts of energy digested per day (Table 1). It appears from the interaction analyses that bran had its greatest effect in the absence of antibiotics and when plant protein was used as the supplement.

Bran consistently increased the apparent digestibility of protein in the ration. For the experiment as a whole the bran-supplemented diets

yielded a coefficient of 75 per cent as opposed to 72 per cent for bran-free diets (Table 2). In no instance was the digestibility coefficient for a bran-free diet as high as its counterpart. However, it is obvious from the statistical tests that bran exerted its greatest effect when used in conjunction with rations fed as meal rather than as pellets and when the supplementary protein was of plant origin. The effect of pelleting is of special interest because, whereas pelleting improved energy digestibility in some types of rations (9), it appeared to counteract much of the potential benefit of added bran as far as protein digestibility was concerned.

Antibiotics appeared to have a relatively small effect on digestibility of energy and protein. While it is evident (Table 2) that protein digestibility was enhanced by bran to a greater extent in the presence than in the absence of antibiotics (76.1 versus 72.1 per cent; 73.6 versus 71.0 per cent, respectively), it is also apparent from the interaction effects that antibiotics, like bran, had their greatest effect in meal-type rations containing no animal protein.

The findings in this experiment, that the inclusion of 10 per cent bran in approximately isocaloric diets (75 per cent T.D.N.) resulted in a 6 per cent increase in feed intake ($P = <.01$) and an 8 per cent increase in protein digestibility ($P = <.01$) for the experiment as a whole, indicate that bran contributed more than was apparent from its nutrient content *per se*. The more pronounced effect of bran in conjunction with antibiotic-free animal protein-free, meal-type rations (18 per cent more feed consumed; 28 per cent more energy digested) suggests involvement with intestinal micro-organisms. In this regard it is recalled that antibiotics and bran were about equally effective in producing growth and feed intake responses. It is not clear to what extent vitamin supply or synthesis may have been involved in this study but a comparison of published data on vitamin requirements (10) with calculated B-vitamin content of the diets (4, 5) revealed that riboflavin supply was only 75 per cent of the requirement. The pantothenic acid supply allowed no margin of safety. Bell *et al.* (2), however, have reported satisfactory performance by growing swine fed antibiotic-supplemented rations similarly 'deficient' in riboflavin and pantothenic acid.

The generally favourable effect of bran on protein digestibility, contrasting with its failure to modify energy digestibility, suggests that bran enhanced the functioning of proteolytic enzymes or improved the assimilation of amino acids. One or both of these may have had some bearing on the improved gains and feed intakes observed because increased protein digestibility could ameliorate amino acid deficiencies to some extent (9).

The failure of bran to modify energy digestibility may be associated with the sites of digestion and absorption and the relative rates at which starch and protein are digested. For instance, little if any amino acid absorption could be expected in the stomach or upper intestine, whereas appreciable quantities of starch products could be digested in this region. The more extensive sequence of proteolytic reactions therefore may have responded to improved physical conditions created by bran in the lower gut, as suggested by Sheehy (12).

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Saskatchewan Federated Cooperatives prepared the pelleted ration used in the experiment.

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INGREDIENT AND PROCESSING INTERRELATIONSHIPS IN SWINE FEEDS

III. EFFECTS OF WHEAT BRAN, PELLETING AND PROTEIN SOURCE ON RESPONSES TO DIETARY ANTIBIOTICS

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ABSTRACT

This is the third in a series of reports on the growth, feed consumption and digestibility responses of growing pigs (50 to 110 pounds in weight) involved in a 2 x 2 x 2 x 2 factorial study of 0 vs. 10 per cent wheat bran, meal vs. pellets, 0 vs. 33 p.p.m. mixed antibiotics and plant versus animal-plant-origin protein supplements. The antibiotic mixture contained penicillin, streptomycin and chlortetracycline in the ratio 5:15:10.

The growth and feed consumption response to antibiotics was generally favourable ($P = <.05$), but the greatest effects were observed on meal-type rations devoid of both animal protein and bran. In some cases antibiotics promoted more efficient conversion of feed dry matter into weight gains but usually the increased gains were due to increased feed intakes. The possibility of enhanced B-vitamin supply or utilization is discussed.

Antibiotics effected an increase in energy digestibility but had relatively little effect on digestibility of protein. As with gains and feed intake responses the most marked energy digestibility effects occurred with meal rations that were bran-free and animal protein-free. Thus energy digestibility increases and feed intake increases largely accounted for the increased gains on these diets.

The failure of antibiotics to effect as good responses in pelleted as in meal rations, or in the presence of bran or with animal protein, is discussed in relation to the matter of encouraging maximum feed intake and particularly with reference to ingesta behaviour and characteristics in various parts of the gastrointestinal tract.

INTRODUCTION

Antibiotics as ingredients of swine rations have been extensively studied. The review by Braude *et al.* (2) is one of several in this field. The benefits from antibiotic feeding have included faster rates of gain, keener appetites and improved feed efficiency. The latter has been related to thinning of the intestinal wall, thus improving the mechanism and efficiency of nutrient absorption (3, 6). The manner in which this thinning occurs is unknown, although Coates *et al.* (6) have presented several postulations. A reduction in pathogenic organisms may, by a reduction in the quantity of toxins produced, cause the intestinal wall to lay down fewer epithelial cells to prevent absorption of harmful substances. Heggeness (11) observed an increase in the absorption of calcium and magnesium from the rat intestine when a broad spectrum antibiotic was fed.

It is well known that extreme variations in activity or types of intestinal micro-organisms can affect rate of passage of ingesta. It is possible that dietary antibiotics might modify passage rates through their influence on micro-organisms. However, there are contradictory reports on this potential relationship (12, 13, 14). Evans and Maguire (8) found that penicillin and aureomycin (chlortetracycline) had no bactericidal or bac-

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teriostatic effects on cellulose-splitting organisms in the pig intestine. Brown *et al.* (4) detected no appreciable change in rate of passage of ingesta in swine following antibiotic feeding.

This report is the third in a series and concerns the influence of pelleting, inclusion of bran and type of protein supplement on the efficacy of mixed antibiotics in rations fed to growing swine.

MATERIALS AND METHODS

The experiment from which the results presented here were obtained has been described in detail (9). The pigs weighed 50 pounds initially and completed the test when they reached 110 pounds. The antibiotic mixture consisted of equal parts by weight of Prostrep[1] and Aurofac-10[2].

The experiment was of factorial design and involved 0 and 33 p.p.m. antibiotic, 0 and 10 per cent wheat bran, meal and pellets and plant versus animal-plant mixed origin protein supplement.

RESULTS AND DISCUSSION

Dietary antibiotics resulted in an over-all increase in both daily gains and feed consumption (Table 1). While antibiotics were generally beneficial throughout this experiment in these two respects, the various interaction results indicate that the greatest effects were obtained when the diet was fed as meal rather than as pellets and contained neither bran nor animal protein.

A superior antibiotic response to all-plant diets has been reported previously (2, 7) and has been related to improved appetite (7). However, in a study of this type, the phenomenon of appetite is too obscure and too complex in origin to reveal much regarding mode of action of antibiotics and their interrelationships with other factors.

It has been reported that the presence of supplementary vitamin B_{12} enhances the growth-promoting action of antibiotics in all-plant origin diets (2, 5). The plant-protein rations in this study contained added vitamin B_{12} but it was assumed that the meat meal in the other rations provided adequate vitamin B_{12}. It, therefore, seems doubtful that this vitamin is implicated in the results obtained.

Of interest also is the finding (Table 1) that antibiotics resulted in significant ($P = <.01$) improvement in efficiency of feed conversion on mixed protein, bran-free meal-type rations. This is apparent from the gains adjusted to uniform dry matter intake even though the effects are not readily seen from the observed gains or feed intakes. Thus, with plant protein rations, the increased gains were associated with greater feed intakes and while with rations containing animal-origin proteins the growth response was low ($P = > .05$) the efficiency of feed utilization was enhanced. Since there were no differences in digestible energy or digestible protein intakes it is probable that vitamin supply or utilization was involved. This possibility has been discussed previously (1, 10).

[1]Courtesy of Merck and Co., Ltd., Montreal. Prostrep contains 5 gm. procaine G. penicillin and 15 gm. streptomycin per pound.
[2]Courtesy of N. D. Hogg Ltd., Toronto. Aurofac-10 contains 10 gm. chlortetracycline per pound.

TABLE 1. — EFFECTS OF PELLETING, TYPE OF PROTEIN SUPPLEMENT AND THE INCLUSION OF BRAN ON THE GROWTH AND FEED CONSUMPTION RESPONSES OF GROWING SWINE

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics
All treatments	32	1.14[1]	1.21*	3.24	3.38*	1.16	1.19	4.64	5.02**	.373	.409**
Pelleting effects											
Meal	16	1.10	1.22*	3.21	3.37	1.13	1.20*	4.56	4.99**	.377	.408**
Pellets	16	1.14	1.21	3.26	3.40	1.16	1.18	4.72	5.05*	.369	.410**
Protein source											
Mixed protein	16	1.16	1.23	3.32	3.41	1.16	1.20	4.84	5.04	.385	.403
Plant protein	16	1.12	1.18	3.15	3.36*	1.18	1.16	4.44	5.01**	.361	.416**
Bran treatments											
Nil	16	1.10	1.19*	3.12	3.30	1.16	1.19	4.40	4.90**	.351	.383**
Bran	16	1.18	1.22	3.35	3.47	1.17	1.16	4.88	5.15*	.395	.435**
Pelleting x protein interaction											
Meal + mixed protein	8	1.14	1.25	3.41	3.39	1.10	1.22**	4.98	4.93	.409	.393
+ plant protein	8	1.06	1.19*	3.01	3.35*	1.16	1.18	4.13	5.06**	.345	.424**
Pellets + mixed protein	8	1.18	1.22	3.24	3.44	1.20	1.18	4.69	5.15*	.361	.413**
+ plant protein	8	1.18	1.17	3.29	3.36	1.19	1.15	4.76	4.96	.378	.408
Pelleting x bran interaction											
Meal + no bran	8	1.03	1.24*	3.07	3.34*	1.11	1.23**	4.24	4.96**	.349	.385*
+ bran	8	1.17	1.20	3.35	3.40	1.16	1.17	4.87	5.02	.405	.431
Pellets + no bran	8	1.16	1.14	3.18	3.26	1.20	1.16	4.56	4.84	.354	.381
+ bran	8	1.20	1.25	3.35	3.54	1.19	1.17	4.88	5.27*	.385	.439**

TABLE 1. — EFFECTS OF PELLETING, TYPE OF PROTEIN SUPPLEMENT AND THE INCLUSION OF BRAN ON THE GROWTH AND FEED CONSUMPTION RESPONSES OF GROWING SWINE—(Continued)

Treatment	n	Weight gains (lb./day)		Feed intake (lb. dry matter/day)		Gains adjusted for feed intake (lb./day)		Energy digested (therms/day)		Protein digested (lb./day)	
		Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics
Protein x bran interaction											
Mixed protein + no bran	8	1.11	1.22	3.29	3.30	1.12	1 22**	4.75	4.93	.379	.373
+ bran	8	1.21	1.24	3.36	3.53	1.19	1.16	4.92	5.14	.391	.433*
Plant protein + no bran	8	1.08	1.16	2.96	3.30*	1.20	1.16	4.06	4.87**	.324	.394**
+ bran	8	1.16	1.20	3.34	3.41	1.15	1.17	4.83	5.15	.399	.438
Pelleting x protein x bran interactions											
Meal + mixed protein + no bran	4	1.10	1.26	3.38	3.30	1.08	1.26**	4.87	4.87	.398	.365
+ bran	4	1.18	1.24	3.43	3.48	1.14	1.18	5.10	4.98	.420	.420
+ plant protein + no bran	4	0.96	1.22*	2.76	3.38**	1.15	1.20	3.62	5.06**	.300	.405**
+ bran	4	1.17	1.16	3.26	3.32	1.19	1.16	4.64	5.07	.390	.443*
Pellets + mixed protein + no bran	4	1.12	1.19	3.21	3.30	1.15	1.19	4.63	4.99	.360	.380
+ bran	4	1.24	1.25	3.28	3.58	1.25	1.16	4.75	5.30*	.363	.445**
+ plant protein + no bran	4	1.20	1.09	3.15	3.22	1.26*	1.12	4.49	4.68	.348	.383
+ bran	4	1.15	1.25	3.42	3.51	1.11	1.18	5.02	5.24	.408	.433

[1]For necessary differences see reference (9)
*Differences significant at P = .05
**Differences significant at P = .01

The effects of antibiotics on ration digestibility are shown in Table 2. In contrast to the effects of bran (10), antibiotics exerted their greatest effects upon the energy or non-protein fractions of the diet. In view of this obvious differential effect of antibiotics on energy (carbohydrate and fat) and protein digestibility one may question the extent to which thinning of the intestinal wall (3, 6, 11) affected the results of this experiment. These findings support those of Vonk *et al.* (15), who observed that the increase in hydrolase activity per unit of ingesta dry matter associated with the inclusion of chlortetracycline in the diet was approximately twice as great for amylase as for protease. There were, of course, some instances in which antibiotics significantly ($P = <.05$) improved protein digestibility but the differences observed were neither large nor readily explained. By contrast, the effects of antibiotics on energy digestibility tend to follow the previously established pattern (10). The most pronounced benefits were obtained on meal-type rations devoid of bran and animal protein. The fact that pelleting or addition of bran or inclusion of animal protein resulted in nearly or equally as good energy digestibility coefficients as were obtained by the use of antibiotics, plus the finding that these effects apparently were non-additive, strongly suggests that their functions were being mediated through the same basic pathway, namely the physical state of the ingesta and its effects, in turn, on microbiological activity.

Relating the energy and protein digestibility coefficients (Table 2) back to the daily intakes of dry matter (Table 1), it is apparent that antibiotic feeding rather consistently increased the daily quota of digested protein and energy. This occurred partly through increased dry matter intakes, partly through small increases in protein digestibility, but primarily through improved energy digestibility. The most marked effect, in accord with the gains and the feed intakes of the pigs, occurred with rations that were fed in the meal form and that were free from animal protein and bran.

It may be concluded from this experiment that, while it was possible to confirm the usual practical advantages of antibiotic feeding, certain of the effects of antibiotics in the gastrointestinal tract may be duplicated or modified by other dietary ingredients or by processing methods such as pelleting.

There are several methods of achieving increased nutrient assimilation. These include modified palatability as indicated by odour, taste and texture; stomach reaction of the ingesta with special attention both to degree and rate of food swelling and to stomach-emptying time; physical consistency of ingesta as it affects enzymatic activity and, finally, the volume or bulkiness of ingesta in the small and large intestines, which influences peristaltic rate. Findings relative to these relationships have been referred to previously (9, 10) and it is possible that some or all of these factors were involved in this experiment. The failure of the beneficial effects of pelleting, bran and antibiotics to be significantly additive may reflect the ability of the pigs to satisfy their full appetite for energy when at least one of the favourable ration characteristics prevailed. Further work is needed to assess these interrelationships under fully *ad libitum* feeding conditions.

TABLE 2. — EFFECT OF MEAL OR PELLETS, MIXED OR PLANT-ORIGIN PROTEIN, AND BRAN FEEDING ON DIGESTIBILITY COEFFICIENTS OF SWINE RATIONS CONTAINING 0 OR 30 P.P.M. ANTIBIOTICS

Treatment	n	Digestibility coefficient (%)					
		Dry matter		Gross energy		Crude protein	
		Nil	Antibiotics	Nil	Antibiotics	Nil	Antibiotics
All treatments	16	73.1[1]	74.8**	73.4	75.3**	72.3	74.1
Meal	8	72.2	74.9**	72.5	75.3**	73.5	74.6
Pellets	8	73.9	74.6	74.3	75.4	71.1	73.6
Mixed protein	8	74.2	74.4	74.6	74.9	72.5	73.3
Plant protein	8	71.9	75.1**	72.2	75.7**	72.1	74.8*
Nil	8	72.7	74.8**	73.0	75.4*	71.0	72.1
Bran	8	73.4	74.7*	73.7	75.2	73.6	76.1
Meal + mixed protein	4	74.3	73.7	74.8	73.8	75.2	72.3
Meal + plant protein	4	70.2	76.1**	70.1	76.7**	71.9	76.8*
Pellets + mixed protein	4	74.2	75.2	74.3	76.0	69.9	74.4*
Pellets + plant protein	4	73.6	74.0	74.3	74.7	72.4	72.9
Meal + nil	4	71.1	75.2**	71.3	75.6**	71.6	71.9
Meal + bran	4	73.4	74.6	73.6	75.0	75.5	77.2
Pellets + nil	4	74.4	74.5	74.7	75.3	70.5	72.3
Pellets + bran	4	73.4	74.8	73.9	75.5	71.8	75.0
Mixed protein + nil	4	74.6	75.3	74.9	75.9	72.0	71.9
Mixed protein + bran	4	73.8	73.6	74.2	73.9	73.1	74.7
Plant protein + nil	4	70.8	74.4**	71.1	74.9**	70.1	72.2
Plant protein + bran	4	73.0	75.8**	73.3	76.6*	74.1	77.5

[1]For necessary differences see reference (9)
*Difference significant at P = .05
**Difference significant at P = .01

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THE FEEDING OF RYE TO GROWING CHICKENS[1]

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ABSTRACT

Four experiments were carried out with growing chickens to study the feeding value of rations containing rye. Levels of rye in the rations ranged from 0 to 60 per cent. The criteria employed to evaluate this effect were body gain, feed efficiency, and carcass grade.

All-mash rations containing rye resulted in poorer growth and feed efficiency than similar rations containing wheat. Pelleting was found to improve the feeding value of rye by the chicken. Pelleted rations containing rye gave growth and feed efficiency equivalent to that obtained on all-mash rations containing wheat. Increasing levels of rye from 15 to 60 per cent in pelleted rations had no significant effect on weight gains but each increment of rye resulted in a noticeable (but non-significant) loss in feed efficiency.

INTRODUCTION

The feeding of rye to poultry and livestock has never been encouraged on this continent. This stems from its characteristic unpalatability and from the general availability of superior cereals. In spite of the rapid advances in nutrition and feeding practice witnessed in the last few decades, little has been done to improve the feeding value of rye.

Nearly 30 years ago Halpin and Holmes (4, 5, 6) established that substitution of rye for corn in chick rations resulted in retarded growth. When rye comprised more than 15 per cent of a ration they observed a condition of sticky droppings. More recently Fangauf *et al.* (3) replaced wheat, barley, and wheat-bran with various levels of rye and encountered higher mortality and sticky droppings at a level of 30 per cent rye. Nevertheless, these authors recommended the use of up to 20 per cent rye in poultry diets, based upon the general condition of their rye-fed chickens.

Attempts to improve the nutritive value of various cereals in the past few years have involved water soaking, cooking, and water extraction, as well as the enzyme supplementation, pelleting, and crumbling of the entire ration. In preliminary investigations in this laboratory designed to improve the feeding value of rye, the cereal was water soaked, cooked, water extracted, sprouted, autoclaved, extracted with ether, supplemented with fat, supplemented with enzymes, and pelleted. Water soaking, cooking, ether extraction with fat supplementation, enzyme supplementation, and pelleting all resulted in improved feed value as measured in chick growth trials. However, at no point did the feeding of the treated rye bring about growth equivalent to that of the treated or untreated rations containing corn[2].

Allred *et al.* (2) demonstrated significantly better chick growth from simply pelleting the single grain, as compared to water soaking or autoclaving the rye, although this increased growth was not equivalent to that

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[2]Smith, R. E., and T. M. MacIntyre, Research Branch, Canada Department of Agriculture, Nappan, N.S. The feeding of rye to growing chickens. *Unpublished research.*

TABLE 1.—COMPOSITION OF THE CONCENTRATE PORTION OF THE RATION AS A PER CENT OF THE TOTAL RATION

Ingredients	Starting ration (1-5 weeks)	Growing ration (5 weeks—term.)
Soybean oil meal (44% protein)	20.00	12.50
Ground oats	4.50	12.50
Fishmeal (65% protein)	4.10	2.80
Meatmeal (50% protein)	3.90	2.30
Stabilized animal tallow	—	3.00
Alfalfa meal (deh. – 17% protein)	3.00	2.50
Buttermilk (dried)	2.00	1.50
Bonemeal (steamed)	1.50	1.20
Limestone	—	0.50
Salt (I_2)	0.50	0.50
Nicarbazine	.05	.05
Vitamins, minerals and additives*	.45	.65
	40.00	40.00

*To provide per pound of ration: manganese 25 mg., choline 600 mg., vit. D_3 90 I.C.U., vit. A 1200 I.U. (source – fish oil), vit. B_{12} 3 mg., D-L methionine 2 mg., riboflavin 1.3 and 0.8 mg. respectively, niacin 12 and 15 mg. respectively, antibiotic 1.5 mg.

TABLE 2.—COMPOSITION OF BASAL RATIONS (POUNDS)

Ingredients	Experiment 1+2 (Starting diets)	Experiment 3 (Starting diets)	Experiment 4 (Starting diets)	Experiment 1+2 (Growing diets)	Experiment 3 (Growing diets)	Experiment 4 (Growing diets)
Concentrate	40	40	40	40	40	40
Ground oats	5	5	—	—	—	—
Ground corn	25	20	—	30	25	—
Ground wheat	30	35	60	30	35	60
Total	100	100	100	100	100	100

of the chicks on the control rations. Lindblad *et al.* (7) have also indicated that higher levels of barley may be fed if the entire ration is pelleted.

In view of the response indicated above, and because of its practicability, the effect of pelleting on rations containing rye appeared to be worthy of investigation.

MATERIALS AND METHODS

Four experiments involving essentially the same procedure, were carried out. Day-old R. I. R. x L. S. crossbred chicks were reared in pens allowing 1.25 square feet of floor space per bird. Heat lamps were provided to 4 weeks of age. A 14-hour lighting schedule was enforced thereafter. Feed and water were supplied *ad libitum* and chick-size grit was fed by sprinkling 5 pounds on the litter in each pen weekly. Feed consumption by pens and individual body weights were recorded.

The percentage composition of the concentrate portion of the diets (Table 1) was the same for all experiments and the customary practice

TABLE 3.—EFFECT OF PELLETING AND REGRINDING RATIONS CONTAINING RYE UPON THE GROWTH AND FEED EFFICIENCY OF BROILERS AT 10 WEEKS (EXPERIMENT 1)

Level of rye (per cent)	Form of feed	Mean gain (pounds)	Feed/gain (pounds)
0[1]	Mash	2.74	3.07
0	Pellets[3]	3.35*	2.77*
30[2]	Mash	2.31*	3.22
30	Pellets[3]	3.02	3.03

[1] Basal ration as shown in Table 2.
[2] Rye substituted for wheat in basal ration
[3] Reground to mash consistency
*Significant (P = .0.5) from control-mash ration

TABLE 4.—EFFECT OF CRUMBLING AND PELLETING RATIONS CONTAINING RYE UPON THE GROWTH AND FEED EFFICIENCY OF BROILERS AT 9 WEEKS (EXPERIMENT 2)

		Males	Females	Combined sexes	
Level of rye (per cent)	Form of feed	Mean gain (pounds)	Mean gain (pounds)	Mean gain (pounds)	Feed/gain
0[1]	Mash	3.06	2.31	2.66	2.72
0	Pellets[3]	3.17*	2.42*	2.79*	2.62
30[2]	Mash	2.77*	2.17*	2.47*	2.84
30	Pellets[3]	2.97*	2.28	2.63	2.81

[1] Basal ration as shown in Table 2
[2] Rye substituted for wheat in basal ration
[3] Fed as crumbles to 5 weeks and pellets to 9 weeks
*Significant (P = .05) from control-mash ration

TABLE 5.—EFFECT OF LEVELS OF RYE IN PELLETED RATIONS UPON THE GROWTH AND FEED UTILIZATION OF BROILERS AT 9 WEEKS (EXPERIMENT 3)[1]

Level of rye (per cent)	0[2]	15[3]	20	25	30	35
Mean gain (pounds)	3.10	3.03*	3.00*	3.01*	2.99*	3.02*
Feed/gain	2.78	2.85*	2.88*	2.89*	2.94*	2.92*

[1] Fed as crumbles to 5 weeks and pellets to 9 weeks
[2] Basal ration as shown in Table 2.
[3] Rye substituted for wheat
*Significant (P = .05) from control-pellet ration

of changing the calorie-protein ratio at 5 weeks was employed in all trials. Table 2 shows the composition of the basal rations for the four experiments. The experimental rations consisted of those basal rations with rye substituted for wheat as shown in Tables 3, 4, 5, and 6.

In Experiment 1, four treatments were imposed in a randomized block within 16 pens, each pen containing 100 male chicks. Two rations were fed, one containing 30 per cent wheat, the other containing 30 per cent rye added at the expense of the wheat. The pelleted rations were reground to a mash consistency, resulting in the four treatments shown in Table 3. This experiment was terminated at 10 weeks.

TABLE 6.—EFFECT OF PELLETED RATIONS CONTAINING HIGH LEVELS OF RYE UPON THE GROWTH AND FEED UTILIZATION OF BROILERS AT 9 WEEKS (EXPERIMENT 4)

	Mash		Pellets[1]									
Level of rye (per cent)	0[2]		0		15[3]		30		45		60	
Sex	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean gain (pounds)	3.05	2.37	3.02	2.52	3.16	2.40	2.98	2.30	3.08	2.27	2.80*	2.25
Feed/gain	2.72	2.82	2.63	2.77	2.64	2.83	2.74	2.92	2.75	3.01	2.92*	2.97

[1] Fed as crumbles to 5 weeks and pellets to 9 weeks
[2] Basal ration as shown in Table 2
[3] Rye substituted for wheat

*Significant (P = .05) from control-mash ration

In Experiment 2, straight-run chicks were utilized with equal numbers of males and females per pen. Four treatments, i.e., 30 per cent wheat and 30 per cent rye in mash and pellet form, were imposed upon the 16 pens in four replications. The pelleted rations were fed as crumbles to 5 weeks and as pellets from 5 weeks to the termination of the experiment at 9 weeks.

The third experiment was designed to establish a level of rye that could be incorporated in pelleted rations which would maintain growth comparable to that of a standard ration in pellet form. A control ration similar to that of Experiments 1 and 2, but consisting of 35 per cent wheat (Table 2), was compared with rations of 15, 20, 25, 30 and 35 per cent rye, the rye in all cases being substituted for the wheat. Ninety male chicks were placed in each of 24 pens with the six treatments imposed in a randomized block design in four replications. All rations were fed as crumbles to 5 weeks, and as pellets from 5 weeks to termination. At 9 weeks the birds were slaughtered and individually graded by professional graders[1].

Experiment 4 extended the level of rye feeding to determine maximal amounts of rye which could be fed to growing chickens. A control mash ration containing 60 per cent wheat (Table 2) was compared with pelleted rations containing 0, 15, 30, 45 and 60 per cent rye. Ninety chicks were placed in each of 24 pens. Twelve pens contained males, and twelve pens contained females. The six treatments outlined above were randomized into two blocks of 4 pens each, twice replicated with two sexes. All rations were fed as crumbles to 5 weeks and as pellets from 5 to 9 weeks. At 9 weeks the birds were slaughtered and individually graded by professional graders[2].

RESULTS AND DISCUSSION

Results of Experiment 1 are presented in Table 3. The inclusion of 30 per cent rye in a mash ration resulted in significantly reduced gains ($P = .05$)[3] and substantially lower feed conversion. These results are supported by earlier work (4, 5, 6). While "pasting" in the groups fed rye was not abnormal, the condition of the litter was quite unsatisfactory due to the tacky droppings and high moisture content. The greatest gains and most efficient feed utilization were shown by the birds receiving the wheat-pelleted, reground, ration. Allred *et al.* (1) likewise demonstrated growth responses to pelleting, even when the pellets were reground to a particle size and density similar to the original mash. A comparison of the wheat-mash and rye-pellet groups shows that the rye-pellet ration produced a heavier bird on slightly less feed at 10 weeks. However, the weights and feed efficiency attained by the birds on the wheat-mash ration appeared lower than would be expected. It was, therefore, considered advisable to test the effect of feeding these rations in crumble and pellet form.

The results of this second trial are presented in Table 4. Growth of the birds on the wheat-mash ration in this trial appears quite acceptable for 9-week birds. The 30 per cent rye-mash ration exhibited its poor feeding quality by significantly lower body gains and low feed efficiency, while

[1]Courtesy, A.C.A. Co-operative Association Ltd., New Minas, N.S.
[2]Courtesy, Eastern Co-operative Services, Sydney, N.S.
[3]Goulden, C. H. 2nd ed. Analysis of variance.

the wheat-pellet ration has shown its superiority over its mash counterpart. Of particular interest is the similarity of results between the wheat-mash and rye-pellet groups. In general, these two experiments have indicated that 30 per cent rye, when fed in pelleted broiler rations, can be considered equal to an all-mash ration containing an equivalent amount of wheat.

The results of Experiment 3 (Table 5) demonstrate the superiority of the wheat-pelleted ration over the rations containing rye. The similarity of gains on the rye rations show that increasing levels of rye from 15 to 35 per cent had no effect on body gains. However, feed-gain ratios demonstrate a noticeable loss of feed efficiency with increasing rye levels, even though statistical differences were not attained within the rye treatments.

Experiment 3 did not indicate the amount of rye in pelleted rations which would interfere seriously with normal growth. For this reason, Experiment 4 employed rations with much higher levels of rye. The levels of rye fed and the results obtained are presented in Table 6. Unlike Experiments 1 and 2, pelleting did not improve the response to the control ration. Body weight gains of the birds appeared to be in keeping with previous experiments. Statistical differences in body weight gain and feed efficiency appeared only at the 60 per cent level of rye in the male groups.

TABLE 7.—EFFECT OF PELLETED RATIONS CONTAINING RYE UPON CARCASS QUALITY (EXPERIMENTS 3 AND 4)[1]

Experiment 3

	Pellets[2]					
Level of rye (per cent)	0	15	20	25	30	35
Grade						
A	95.1	94.6	93.3	90.4	95.6	95.3
B	2.5	3.5	4.5	8.8	2.2	2.9
C	0.8	0.5	1.1	0.5	1.6	0.9
Cull	0.2	0.0	0.3	0.0	0.0	0.3

Experiment 4

		Mash	Pellets[2]				
Level of rye (per cent)		0	0	15	30	45	60
Grade	Sex						
A	M	68.9	71.0	65.5	50.0	38.7	32.2
	F	52.9	78.5	59.5	58.3	46.9	20.4
B	M	15.2	23.4	26.2	34.1	44.7	38.8
	F	32.7	15.7	29.5	33.1	39.4	48.6
Culls	M	10.4	0.0	0.0	9.9	9.2	17.5
	F	8.1	0.0	4.2	0.0	7.9	19.5

[1] Percentage commercial grades
[2] Fed as crumbles to 5 weeks and pellets to 9 weeks

Even though statistical differences were not present within the female groups, their body weight gain appears to fall off with increasing levels of rye. It must be noted that differences would have to be quite large for statistical significance due to the small number of replications brought on by the separate analyses for sexes. Consideration of feed-gain ratios for both sexes reveals an increase in feed required per pound of gain with rye inclusions at all levels, as in the previous experiments.

In order to determine the effect of rations containing relatively high proportions of rye upon carcass quality, all birds in Experiments 3 and 4 were individually graded by professional graders (Table 7). The data of Experiment 3 demonstrates that the feeding of rye, up to 35 per cent of the ration, does not reduce the finish of the bird. The birds of Experiment 4 did not grade as well nor as uniformly as those of Experiment 3. Since most of the corn had to be removed from the basal mixture to allow for a 60 per cent inclusion of rye or wheat, slightly lower carcass grades might be expected. In addition, these birds were exposed to severe winter shipping conditions for a period of more than 15 hours. The large number of culls reported are due in part to the stress imposed by these conditions. In spite of the major differences between results of the two experiments, the between-treatment data reveal little differences in carcass finish up to a level of 30 per cent rye.

Results of these experiments show that the feeding value of rations containing rye can be improved by pelleting the entire ration. Even with this improvement rye must be considered inferior to wheat in the rations of growing chickens. Although there was a tendency to reduced gains and feed efficiency with increased levels of rye, in no case were the differences between levels of rye significant. These data show that up to 60 per cent of rye may be safely fed to growing chickens if the entire ration is pelleted.

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APPLICATION OF CO-RAL FOR SYSTEMIC CONTROL OF CATTLE GRUBS *HYPODERMA LINEATUM* (DE VILL.) AND *H. BOVIS* (L.)

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ABSTRACT

Sprays of 0.5 per cent (weight by volume) CO-RAL wettable powder (WP) in water applied to the entire body of the unweaned calves on September 12, 1958, reduced warble infestation by 99.5 per cent and gave significantly better control ($P < 0.01$) than similar treatments with CO-RAL emulsifiable concentrate (EC) or WP on October 30, 1958. Topline spraying in October with 0.75 per cent CO-RAL EC was as effective as similar over-all sprays applied at the same time or 0.5 per cent CO-RAL WP sprayed over-all 6 weeks earlier. There was no significant difference between the efficacies of wettable powder and emulsifiable concentrate of CO-RAL.

A recurrence of shipping fever was noticed in the herd sprayed soon after weaning and shipping. This condition was not observed in calves sprayed before weaning. Clinically none of the treated calves showed any cholinergic signs of organophosphate poisoning.

INTRODUCTION

CO-RAL[1] is used for systemic control of cattle grubs, *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.), after the period of adult fly activity and before the appearance of grubs in the backs of infested cattle. This phase in the life cycle of the warble fly extends from September to December in Western Canada. During this period it is not always practical to spray cattle. With the advent of cold weather and freezing temperatures spraying of calves becomes uncertain and hazardous. The heavy coat of winter hair may interfere with the wetting of the skin and the absorption of the insecticide into the animal system. The stresses of weaning, shipping, and, in the case of feedlot animals, high feed intake may increase the susceptibility of calves to the cholinergic insecticide. These stresses working alone or in combination may also lower the resistance of calves to certain dormant pathogens.

However, the detrimental effects of these factors might be overcome or minimized by spraying calves early in the fall, soon after the adult fly season and before weaning. Therefore, in a series of experiments, the effects of spraying calves in September before weaning were compared with the effects of spraying later in the fall after weaning. The effectiveness of sprays applied to the entire animal body or parts thereof and two formulations of CO-RAL, a wettable powder (WP) and an emulsifiable concentrate (EC), were also compared. The concentration of CO-RAL was increased to 0.75 per cent in partial coverage to compensate for the reduced quantities of spray applied. The tolerance to 0.75 per cent CO-RAL EC sprayed over the entire animal was also studied.

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[1]Trade name for O,O-diethyl O-(3-chloro-4-Methyl-7-coumarinyl) phosphorothioate, which was formerly called Bayer 21/199, and was supplied by Chemagro Corp., Kansas City, Missouri.

MATERIALS AND METHODS

In these experiments conducted at Lethbridge, Alberta, and at Wawanesa, Manitoba, Hereford range calves were used. These calves were born in the spring of 1958 in areas known to be infested with both species of warble flies.

At Lethbridge, 120 weaned calves which had been trucked to the laboratory 10 days earlier over a distance of 150 miles were sprayed on October 30, 1958 (Table 1). These calves weighed 350-450 pounds and were gate-cut at random into six equal groups. In view of earlier studies (1) a group of 20 calves were considered to be an adequate sample size. After spraying, each group was penned separately to prevent transfer of insecticide from one group to the other.

At Wawanesa, the density of grub population was not known. Therefore, each test group was enlarged to 29 calves. These calves were randomly selected and sprayed on September 12. After spraying the calves were returned to their untreated mothers on the range. On that occasion 19 yearling Herefords, weighing 700 to 900 pounds, were also sprayed and pastured in a 5-acre field with an unsprayed group of 19 yearlings.

The sprays were applied at a pressure of 400 pounds per square inch, using 5/64-inch discs. The calves were sprayed in a chute, but the yearlings were sprayed in a crowding pen. Sprays were applied either to the entire body of the animal or to the topline or underline only. Topline sprays covered back, shoulders, sides, and hind-quarters. Underline sprays were limited to brisket, axillae, belly, groins, and inner aspects of the thighs. As far as possible care was taken to wet the skin of the treated areas and not the hair alone. The quantity of spray fluid applied to an animal was estimated by the amount of time spent in spraying an animal with spraying guns of known output per minute.

The number of hypodermic grubs squeezed out of the back of a treated animal was used as an estimate of the pre-hypodermic grubs surviving the treatment. The hypodermic grubs were collected bi-weekly at Lethbridge from January 9 to May 15, 1959, and at Wawanesa on January 25, February 26, March 13, April 7, and May 5, 1959. The species of grubs were identified and recorded along with their cumulative count for each animal.

The efficacies of the various treatments and their relative significance were calculated by a method described earlier (1).

At the time of spraying the atmospheric temperature, humidity, and wind velocity were: at Lethbridge 75°F., 11 per cent and 15 miles per hour, respectively; and at Wawanesa 67°F., 52 per cent and 14 miles per hour, respectively.

RESULTS AND DISCUSSION

Systemic Effect of the Insecticide

A significant reduction ($P < 0.01$) was observed in the number of grubs in the calves sprayed at Lethbridge and Wawanesa. However, the reduction in the number of grubs in yearlings at Wawanesa was not so significant ($P < 0.05$) as the mean number of hypodermic grubs per un-

TABLE 1.—COMPARATIVE EFFICACY OF CO-RAL SPRAYS FOR THE SYSTEMIC CONTROL OF CATTLE GRUBS IN WESTERN CANADA

CO-RAL treatment	Location and date	No. of animals sprayed	Spray coverage	Gallons of spray applied per animal	Mean no. of hypodermic grubs per calf with standard error[1]	Estimated percentage of mortality in pre-hypodermic grubs
1. 0.5 per cent wettable powder	Lethbridge October 30, 1958	20 calves	over-all —	2	1.8 ± 0.5	95.7
2. 0.5 per cent emulsifiable concentrate	Lethbridge October 30	20 calves	over-all —	2	1.4 ± 0.4	96.6
3. 0.75 per cent emulsifiable concentrate	Lethbridge October 30	20 calves	over-all —	2	.7 ± 0.5	98.3
4. 0.75 per cent emulsifiable concentrate	Lethbridge October 30	20 calves	topline	¾ to 1	.2 ± 0.5	99.5
5. 0.75 per cent emulsifiable concentrate	Lethbridge October 30	20 calves	underline	¾	11.4 ± 3.8	72.8
6. Water—control group	Lethbridge October 30	20 calves	over-all —	2	42 ± 2	—
7. 0.5 per cent wettable powder	Wawanesa September 12, 1958	29 calves	over-all —	¾ to 1	.1 ± .2	99.5
8. No treatment	Wawanesa September 12	29 calves		—	22 ± 4.1	—
9. 0.5 per cent wettable powder	Wawanesa September 12	19 yearlings	over-all —	1 ⅓	.2 ± .2	93.3
10. No treatment	Wawanesa September 12	19 yearlings		—	3 ± 1	—

[1]Significantly lower than the control at 1 % level for all treatments (1-7), and for treatments No. 1 to 4 and 8 compared with treatment No. 5, and for treatment No. 4 compared with treatment No. 1 or 2. Treatment No. 9 was not included in the analysis of comparative efficacies of various treatments as the mean number of grubs in the respective control was low.

treated yearling was low 3 ± 1 (Table 1). Among other reasons, this may have been caused by accidental transfer of insecticide from treated to untreated animals.

These experiments were not designed to determine the effect of various CO-RAL treatments on cattle lice; but on repeated examinations none of the sprayed or unsprayed calves was found to be infested with lice to any noticeable extent.

Early versus Late Spraying

The unweaned calves sprayed on September 12 with 0.5 per cent CO-RAL WP applied to the entire body had significantly fewer grubs ($P < 0.01$) than the calves receiving similar applications of CO-RAL WP or EC on October 30. The September treatment was as effective as the October treatment with a higher concentration of 0.75 per cent CO-RAL EC sprayed on the entire body or on the topline. The effectiveness of October sprays with 0.75 per cent CO-RAL EC on the topline was also compared with 0.75 per cent CO-RAL WP sprayed on the topline in December 1957 (1). A significant difference ($P < 0.01$) was observed in favour of the October treatment. As explained later, it is doubtful if the higher efficacy of the October treatments was due to the formulation of CO-RAL EC used. The higher efficacy of earlier treatments is possibly caused by one or more of the following factors: (a) shorter hair coat which permits better absorption of the insecticide; (b) greater toxicity to smaller and younger larvae; and (c) location of larvae in more vascular tissues where contact with the insecticide in the blood is greater than in such locations as the esophageal submucosa and the epidural fat in the neural canal, where the larvae may be lodged later.

Approximately ¾ to 1 gallon of spray fluid was required to treat an unweaned calf in September, when the hair coat is short and dries quickly without any risk of chilling. The calves returned to their mothers and did not suffer from any harmful after-effects. For similar treatments applied 6 weeks later it required approximately 2 gallons of spray fluid per calf. By this time the hair coat was long and cooler weather increased the risk of chilling.

The calves used in October treatments were under the stress of weaning and shipping, and a few cases of shipping fever were noticed in the herd soon after their arrival at the laboratory. Shipping fever was quickly controlled by treating the entire herd with sulphonamides. The calves were normal at the time of spraying, but there was a recurrence of shipping fever 2 days after spraying as the atmospheric temperature dropped to 37°F., with winds up to 38 miles an hour. Sick calves were noticed in all groups, including the controls. The entire herd was again treated with sulphonamides to control shipping fever without any loss of animals. None of the sick calves showed any clinical signs of allergy or pronounced neuromuscular involvement.

Partial versus Complete Spraying

At Lethbridge, the topline sprays on October 30 with 0.75 per cent CO-RAL EC were as effective as the same concentration applied to the

entire body, or 0.5 per cent CO-RAL WP sprays applied 6 weeks earlier. However, these topline sprays were significantly more effective ($P < 0.01$) than the over-all sprays with 0.5 per cent CO-RAL WP or EC or the underline sprays with 0.75 per cent CO-RAL EC applied at the same time.

The shape of the animal body makes it easier to spray the topline. The spray streams strike the target area at right angles and force their way through the hair coat to wet the skin and not hair only (2). The absorption of the insecticide into the animal system is not limited to the areas covered by the spray streams, as some of the run-off fluid follows the contours of the animal body and wets the skin of the unsprayed parts.

Wettable Powder versus Emulsifiable Concentrate

There was no significant difference between the relative efficacy of sprays of 0.5 per cent CO-RAL WP and 0.5 per cent CO-RAL EC (Table 1). The latter formulation was easier to handle and mixed readily with water, but it had one disadvantage. CO-RAL crystallized at 21°F. and had to be redissolved with heat*.

Complete Coverage with 0.75 per cent CO-RAL EC

Over-all sprays of 0.75 per cent CO-RAL EC were as effective as similar sprays on the topline or over-all sprays with 0.5 per cent CO-RAL WP or EC. Clinical signs of any cholinergic effect were not noticed in the sprayed calves.

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EFFECTS OF DESICCATED THYROID ON NON-ESTROGENIZED AND ESTROGENIZED SEXUALLY IMMATURE PULLETS[1]

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ABSTRACT

Inclusion of 0.5 per cent desiccated thyroid in the food of unestrogenized immature pullets for 14 days reduced thyroid weight, reduced serum Ca slightly but significantly, increased liver total crude protein, liver total DNAP and total RNAP, but did not alter the ratio RNAP:DNAP in the liver. These results are regarded as indicative of stimulation of growth of liver tissues by the thyroidal treatment.

Daily intramuscular injection of 1.0 mg. estradiol benzoate for 14 days greatly increased serum Ca and liver total crude protein, increased slightly liver total DNAP and increased greatly liver total RNAP and ratio RNAP: DNAP in the liver. The thyroidal treatment reduced estrogen-induced increase of serum Ca and of liver crude protein but did not alter significantly the effects of estrogen on liver DNAP and RNAP.

The thyroidal treatment increased kidney weight in both unestrogenized and estrogenized pullets.

Estrogen treatment increased kidney weight and the percentage of dry matter in the kidney.

The thyroidal treatment did not affect the degree of estrogen-induced hypertrophy of the oviduct.

INTRODUCTION

It is well established that intravenous injection of thyroxine will depress estrogen-induced hypercalcemia in the chick and immature pullet (9, 4). Intravenous thyroxine also depressed liver weight and total liver fat of pullets that had been treated with estrogen plus androgen, but did not affect the degree of hypertrophy of the oviduct induced by this treatment with gonadal hormones (6). It has also been shown that the thyroidal hormone will increase the liver weight of rats (1, 11) and will accelerate regeneration of the liver in partially hepatectomized rats (11). Guggenheim *et al.* (10) have shown that addition of 0.5 per cent desiccated thyroid to the food of rats increased the weight of the liver and the total amount of pentose nucleic acid (RNA). Quite recently Granitsas *et al.* (9) have shown that dietary thyroid increased total liver protein of mice as well as the liver weight.

Previous experiments in this laboratory had been restricted to the examination of the effects of intravenous thyroxine on the responses of immature pullets to gonadal hormones. These observations have now been extended by a study of the effects of thyroidal hormone on the unestrogenized pullet as well as on the estrogenized pullet. The results of this study form the subject of the present paper.

MATERIALS AND METHODS

Thirty-two crossbred (Barred Rock x Rhode Island Red) pullets aged 8 weeks were placed in individual cages. They were given a basal diet that has been described elsewhere (7). Food consumption was kept as nearly equal as possible between groups throughout the experiment by limitation of the daily allowance to slightly below appetite. This was done

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in order to obviate effects that might have arisen from differences in food consumption.

The birds were assigned at random to the following treatments:

Group	O	T	E	ET
No. of pullets in group	8	8	8	8
Estradiol benzoate* mg. per day	nil	nil	1.0	1.0
Dietary desiccated thyroid**, per cent	nil	0.5	nil	0.5

*Given as 'Progynon B' (Schering) by intramuscular injection
**Supplied by Nutritional Biochemicals

The injections of estradiol benzoate (ODB) were begun on the same day as the introduction of desiccated thyroid into the diet and continued for 14 days.

On the morning after the fourteenth successive daily injection of ODB, the birds were killed by decapitation and bled. The ovaries, oviducts, thyroids, livers and kidneys were removed and weighed. Samples of liver were prepared for determinations of deoxyribonucleic acid (DNA) and of pentose nucleic acid (RNA) by the method of Ceriotti (2, 3). The results of the analyses were expressed in terms of deoxyribonucleic acid phosphorus (DNAP) and pentose nucleic acid phosphorus (RNAP). Serum Ca was determined by precipitation of proteins with trichloracetic acid and subsequent titration of the filtrate with EDTA (13). The data were examined by analyses of variance, except where the variance departed widely from homogeneity as between all four groups, as was the case for the data relating to serum Ca and to oviduct weight. The analyses of variance were arranged as follows:

Source of variance	*Degrees of freedom*
Levels of thyroid	1
Levels of estrogen	1
Thyroid x estrogen	1
'Within group' variance	28
Total	31

The results of these analyses of variance are presented in terms of the relevant 'F' values.

In addition to the foregoing analyses of variance, the results for certain appropriate pairs of groups were compared by independent 't' tests. The results of these 't' tests are presented in terms of the relevant 't' values.

RESULTS

The average data together with the results of the statistical analyses are summarized in Table 1.

Live Weight

Neither the initial nor the final live weights displayed significant group differences. There was, however, a tendency for the thyroidal treatment to reduce live weight increase, although this tendency did not attain significance at $P = 0.05$.

Food Consumption

A few of the birds in groups O and T occasionally failed to clear up the amount fed, but it will be seen from Table 1 that this was not sufficient seriously to disturb the uniformity of food consumption as between groups.

TABLE 1.—EFFECT OF DESICCATED THYROID ON UNESTROGENIZED AND ESTROGENIZED SEXUALLY IMMATURE PULLETS. AVERAGE VALUES. 8 PULLETS PER GROUP. DURATION OF TREATMENT—14 DAYS

Group	O	T	E	ET	'F' values			't' values[2]		
Estradiol benzoate, mgm. per day Dietary thyroid %	nil nil	nil 0.5	1.0 nil	1.0 0.5	Thyroid vs. no thyroid	Estrogen vs. no estrogen	Interaction	O vs. T	O vs. E	E vs. ET
Live weight, final, kgm.	1.30 ± 0.03[1]	1.28 ± 0.02	1.31 ± 0.03	1.24 ± 0.03	2.8	0.2	1.0	0.5	0.6	1.8
Live weight increase, kgm.	0.17 ± 0.01	0.14 ± 0.01	0.16 ± 0.02	0.13 ± 0.01	3.9	0.2	0.4	2.0	0.6	1.3
Food consumed, kgm. per bird	0.97	0.97	0.98	0.98	–	–	–	–	–	–
Ovary weight, gm.	0.32 ± 0.03	0.31 ± 0.02	0.24 ± 0.02	0.27 ± 0.02	0.5	9.5**	0.6	0.1	2.6*	1.4
Oviduct weight, gm.	0.17 ± 0.1	0.17 ± 0.1	10.6 ± 1.0	12.3 ± 0.7	–	–	–	–	–	1.4
Thyroid weight, mgm.	89 ± 10	69 ± 4	97 ± 6	68 ± 4	14.0**	0.4	0.5	1.8	0.7	4.1**
Serum Ca, mgm. per 100 ml.										
at 5 days	12.4 ± 1.6	12.3 ± 1.6	43.9 ± 2.5	25.7 ± 2.0	–	–	–	0.0	–	5.8**
at 15 days	12.3 ± 1.6	11.6 ± 0.8	60.0 ± 6.1	35.8 ± 3.6	–	–	–	3.1**	–	3.4**
Liver weight, gm. per kgm.	14.1 ± 0.4	15.5 ± 0.5	22.6 ± 0.9	17.7 ± 0.7	7.5**	80.8**	23.9**	2.3*	8.3**	4.3**
Liver crude protein, per cent	21.9 ± 0.3	23.1 ± 0.2	20.3 ± 0.2	21.9 ± 0.6	13.7**	14.2**	0.2	3.1**	4.0**	2.6*
Liver crude protein, gm. per kgm.	3.1 ± 0.1	3.6 ± 0.1	4.6 ± 0.2	3.9 ± 0.1	0.9	47.3**	22.3**	3.3**	7.6**	3.4**
Liver DNAP, mgm. per kgm.	3.5 ± 0.1	4.1 ± 0.2	4.0 ± 0.4	4.2 ± 0.2	0.7	1.7	0.8	2.6*	1.3	0.5
Liver RNAP, mgm. per kgm.	9.6 ± 0.5	11.1 ± 0.9	17.0 ± 0.3	17.0 ± 0.7	0.7	68.7**	1.1	1.6	6.6**	0.1
Liver RNAP: DNAP	2.8 ± 0.2	2.8 ± 0.3	4.6 ± 0.6	4.0 ± 0.2	1.1	26.3**	0.6	0.2	2.7*	0.8
Kidney weight, gm. per kgm.	4.9 ± 0.2	6.2 ± 0.2	5.4 ± 0.3	6.0 ± 0.2	19.0**	0.4	2.0	4.3**	1.3	2.0
Kidney dry matter, per cent	21.9 ± 0.3	22.0 ± 0.31	23.7 ± 0.3	22.7 ± 0.1	3.7	25.6**	4.5**	0.0	4.7**	3.6**

* Significant at P = 0.05
** Significant at P = 0.01

[1] Figures preceded by ± sign are standard deviations of the mean
[2] 't' values relate to independent comparisons between the pairs of groups indicated

Ovary Weight

The estrogen treatment reduced ovary weight highly significantly but the thyroidal treatment had no demonstrable effect on ovary weight.

Oviduct Weight

Dietary thyroid had no effect on the oviduct weight of the unestrogenized pullets; neither had it any significant effect on the oviduct weight of the estrogenized pullets ('t' for comparison of groups E and ET was only 1.39).

Thyroid Weight

Dietary thyroid reduced thyroid weight highly significantly both in the estrogenized and the unestrogenized pullet. Estrogen had no significant effect on thyroid weight.

Serum Ca

The thyroidal treatment had no significant effect on serum Ca of the unestrogenized pullets at 5 days, but did result in a slight but highly significant reduction ('t' = 3.12 for 14 df) at 14 days.

The thyroidal treatment reduced estrogen-induced hypercalcemia to a highly significant degree ('t' = 5.78 for 14 df) as early as the 5th day of the experiment. The effect was also in evidence at the 14th day.

Liver Weight and Liver Composition

The thyroidal treatment produced a slight increase of liver weight in the unestrogenized pullets, which attained significance when calculated as grams per kilogram live weight. However, the thyroidal treatment increased significantly the percentage of crude protein in the unestrogenized pullets (comparison of groups O and T), and consequently the thyroidal treatment increased liver crude protein highly significantly when calculated as grams per kilogram live weight. The thyroidal treatment increased significantly the liver DNAP of the unestrogenized pullets. The liver RNAP was increased concurrently but the ratio RNAP:DNAP was unchanged.

Estrogen evoked the usual large increases of liver weight and liver crude protein. It also had a slight but significant effect on total liver DNAP, and greatly increased the total liver RNAP and the ratio RNAP:DNAP. The thyroidal treatment decreased the effects of estrogen on liver weight and liver crude protein, although it did increase the percentage crude protein in the liver of the estrogenized birds. The thyroidal treatment did not modify the liver contents of either DNAP or RNAP of the estrogenized pullets, nor did it alter significantly the ratio RNAP:DNAP in the livers of these birds.

Kidney Weight and Composition

The thyroidal treatment increased significantly the kidney weight of both unestrogenized and estrogenized pullets. A slight increase of kidney weight by estrogen treatment (comparison of groups O and E) did not attain significance in this experiment, although estrogen has been shown to increase kidney weight in several previous experiments (7, 15). Estrogen

increased the percentage of dry matter in the kidneys to a highly significant degree. The thyroidal treatment did not affect the dry matter content of the kidney in the unestrogenized pullet in spite of its positive effect on kidney weight, but it reduced significantly the dry matter content of the kidney of the estrogenized pullet.

DISCUSSION

The results have shown clearly that, in a short-term experiment, inclusion of 0.5 per cent dried thyroid in the food will produce the following effects on the liver of the unestrogenized immature pullet: (a) a slight increase in weight and total crude protein; (b) a slight but definite increase in total DNAP; and a slight but definite increase in total RNAP, the ratio RNAP:DNAP being unchanged. The increase in liver crude protein agrees with the observations of Granitsas *et al.* (9) on the livers of mice, although it may be mentioned that these workers fed their mice *ad libitum;* and it is known that a single injection of thyroxine may induce changes in the liver tissue of rats that closely resemble those associated with normal growth (14), as well as an increase in liver protein.

As in numerous previous experiments (5, 6, 7, 15) estrogen produced (a) an increase in liver weight and in total crude protein; (b) a slight but definite increase in total DNAP, this increase being approximately as big as that induced by the thyroidal treatment; and (c) a striking increase in total RNAP and in the ratio RNAP:DNAP. Superimposition of the thyroidal treatment depressed these estrogen-induced responses of liver weight, and liver crude protein, but did not alter the estrogen-induced changes in total DNAP and RNAP. Thus the thyroidal treatment affected liver weight and total crude protein in opposite senses according as the pullets were unestrogenized or estrogenized, i.e., it increased liver DNAP and RNAP of unestrogenized pullets but did not affect DNAP and RNAP of estrogenized birds. These observations, taken together, suggest that thyroidal hormone will stimulate growth of liver tissue in the unestrogenized pullet but will not alter appreciably the similar slight increase of DNAP or the large increase of RNAP induced by estrogen. The results suggest that the increases of liver weight, liver crude protein, and liver DNAP and RNAP evoked by thyroidal hormones are not physiologically equivalent to those evoked by estrogen. It would seem that the estrogen-induced changes are related to the induction of synthesis of potential egg-yolk material in the liver (5) as well as to hyperplasia, whereas the thyroidally-induced changes are related solely to stimulation of growth.

The thyroidal treatment increased kidney weight highly significantly in the unestrogenized birds, a result that is in agreement with Belasco's (1) finding that treatment of rats with thyroidal hormone increased their kidney weight. The positive effect of the thyroidal hormone on kidney weight did not quite attain significance at $P = 0.05$ when only the estrogenized pullets were considered (comparison of groups E and ET). However, the effect may be regarded as real also in the case of the estrogenized pullets, especially in view of the fact that estrogen has usually been found to increase kidney weight in pullets whereas androgen has an opposite effect

(12). In the experiment now reported, estrogen produced a highly significant increase of the percentage of dry matter in the kidney, an effect of estrogen on the pullet that we have not previously observed. Thus the increase of kidney weight induced by estrogen is not due to hydration of the organ.

The data for serum Ca confirmed the depressant effect of thyroidal hormone on estrogen-induced hypercalcemia that had been observed in previous experiments (4, 6). The data now reported show that this effect was statistically significant after only 5 days of treatment. The thyroidal treatment eventually reduced significantly the level of serum Ca of the unestrogenized pullets, an effect that we had not observed previously.

The data show that thyroidal hormone, at the levels used, did not affect the degree of hypertrophy of the oviduct induced by estrogen. In previous work (7), intravenous thyroxine was found slightly to enhance the response of the original estrogen in one experiment and slightly to reduce it in another experiment. It may be concluded that the effects of exogenous thyroid hormone on estrogen-induced hypertrophy of the oviduct are slight and inconsistent, if any.

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EFFECTS OF HIGH FIBRE, AND PELLETED AND NON-PELLETED HIGH FIBRE-HIGH FAT RATIONS ON PERFORMANCE AND CARCASS CHARACTERISTICS OF BACON PIGS

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ABSTRACT

A study involving 96 individually-fed growing-finishing pigs was conducted to determine the effects of high fibre, and pelleted and non-pelleted high fibre-high fat rations, on the performance and carcass characteristics of bacon type pigs.

Rate of liveweight gain, and gains adjusted to equal feed intakes, decreased when the fibre level was increased by substituting ground mixed timothy-red clover hay for part of the barley in the control rations. Rate of gain increased in the finishing period with the introduction of 5 per cent of stabilized tallow into the high fibre rations.

Pelleting the high fibre-high fat rations had little effect on the performance of the pigs in the growing period, while rate of gain increased in the finishing period as a result of the pelleting process. This increase in rate of gain was associated with increased feed intake.

High fibre rations resulted in lower dressing percentage and loin fat thickness, and increased Advanced Registry belly and total scores. The addition of 5 per cent of stabilized tallow to the high fibre rations resulted in increased shoulder and loin fat thickness. Pelleting of the high fibre-high fat rations had no significant effect on carcass measurements, although the pigs fed pelleted rations consumed more feed per day and made more rapid gains in the finishing period than those fed the same rations non-pelleted.

INTRODUCTION

Carcass quality of pigs is improved when fibrous feeds replace part of the basal rations (2, 4, 8). This improvement is usually accompanied by a decreased rate and efficiency of gain which appears to be related to decreased daily digestible energy intake. However, not all fibrous feeds depress rate or efficiency of gain (8). Bohman *et al.* (5) have suggested that factors other than level of fibre may be responsible for the depressed rate of growth and feed utilization reported with high-fibre rations. Peterson (18) found that cottonseed oil had no effect upon the inhibition of growth produced by alfalfa meal in a chick ration, indicating that caloric density was not involved. Merkel *et al.* (16) have reported that the level of crude fibre in the ration was more highly correlated with the results of growth and carcass data than either T.D.N. or protein level. Axelsson and Eriksson (2) found that daily feed consumption increased with increased crude fibre content. More recently Jensen *et al.* (11, 12) reported that the growth reduction caused by oats in rations for growing-finishing pigs was the result of lowered T.D.N. value and feed intake.

This paper summarizes the results of an experiment conducted at the Experimental Farm, Nappan, Nova Scotia, and designed to study: 1) the effects on performance and carcass characteristics when the fibre level was increased by substituting ground timothy-red clover hay for barley, in growing and finishing rations for pigs; 2) the effects of added fat in high fibre rations and pelleting of high fibre-high fat rations based upon the above criteria.

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TABLE 1.—PERCENTAGE COMPOSITION AND CHEMICAL ANALYSIS OF THE GROWING AND FINISHING RATIONS

Ration number	1		2		3		4	
	Control		High fibre		High fibre-high fat			
					Non-pelleted		Pelleted	
Ration description	Barley		Barley, timothy-clover hay		Barley, timothy-clover hay, tallow		Barley, timothy-clover hay, tallow	
Ingredients	Percentage Composition—air dry basis							
	Grower	Finisher	Grower	Finisher	Grower	Finisher	Grower	Finisher
Barley	88.0	94.5	72.5	67.5	65.25	61.0	65.25	61.0
Mixed timothy-clover hay	—	—	15.0	25.0	15.0	25.0	15.0	25.0
Stabilized tallow	—	—	—	—	5.0	5.0	5.0	5.0
Soybean oilmeal	6.0	2.25	6.75	3.75	8.0	4.5	8.0	4.5
White-fish meal	4.25	1.5	4.5	2.5	5.5	3.25	5.5	3.25
Common ingredients[1]	1.75	1.75	1.25	1.25	1.25	1.25	1.25	1.25
	Chemical Analysis — dry matter basis							
Protein (N x 6.25)	17.8	14.3	17.7	13.9	17.9	14.5	17.7	14.6
Crude fibre	5.6	5.6	9.7	12.8	8.9	11.4	9.1	10.4
Ether extract	2.4	2.4	2.4	2.1	8.0	7.5	7.3	7.4
Ash	5.4	4.5	5.8	5.3	5.5	5.5	5.6	5.7
N.F.E.	68.7	73.3	64.3	65.9	59.7	61.1	60.3	61.9

[1]Ground limestone, 1.0% in control rations and 0.5% in all other rations; iodized salt, 0.5%; vitamin B_{12} antibiotic supplement (10 gm. Chlortetracycline per lb.), 0.05%; feeding oil (1500A-300D), 0.2%

MATERIALS AND METHODS

Design of the Experiment

The treatments (winter versus summer farrow; barrow versus gilt; and four ration combinations) were arranged in a 2 x 2 x 4 factorial design. Six pigs were used in each of the sixteen treatment combinations giving a total of ninety-six experimental animals.

Rations

The formulation and chemical composition of the rations fed during the growing and finishing periods are presented in Table 1. Ground first-cut timothy-red clover hay replaced barley to the extent of 15 and 25 per cent of the rations in the high fibre growing and finishing rations, respec-

TABLE 2.—ANALYSIS OF VARIANCE PLAN

Source of variance	Degrees of freedom
Season	1
Sex	1
(1)[1] vs. (2) + (3) + (4)	1
(2) vs. (3) + (4)	1
(3) vs. (4)	1
Season x Sex	1
Season x (1) vs. (2) + (3) + (4)	1
Season x (2) vs. (3) + (4)	1
Season x (3) vs. (4)	1
Sex x (1) vs. (2) + (3) + (4)	1
Sex x (2) vs. (3) + (4)	1
Sex x (3) vs. (4)	1
Season x Sex x (1) vs. (2) + (3) + (4)	1
Season x Sex x (2) vs. (3) + (4)	1
Season x Sex x (3) vs. (4)	1
Experimental error	80

[1]Brackets indicate ration number

tively. The timothy-red clover hay was ground in a hammer mill through a 3/32-inch screen. Stabilized tallow was added to the extent of 5 per cent of the ration in the high fat rations. Barley, soybean oil meal and fish meal were varied to provide a calculated level of 17 per cent crude protein for the growing period, (38 ± 5 to 105 ± 5 pounds body weight) and 14 per cent crude protein for the finishing period (105 ± 5 pounds to the market weight of 200 ± 10 pounds). The pelleted rations were pelleted through 3/16 inch dies.

All rations were analysed according to A.O.A.C. methods (1).

Animals

The pigs used were purebred Yorkshires, raised at the Experimental Farm, Nappan, Nova Scotia. All pigs were by the same sire and from sows that were half or full sisters. The pigs were penned individually on concrete floors in a heated experimental piggery. Feed and water were provided *ad libitum*. The male pigs were castrated at 2 weeks of age. All pigs were weaned at 8 weeks of age and started on experiment at a weight of 38 ± 5 pounds. Individual weights of the pigs and their feed consumption were recorded bi-weekly. Carcass measurements and scores were obtained as outlined in Canadian Advanced Registry for Swine standards (3). Commercial grades were obtained on all carcasses.

Data Analysis

The data were subjected to analysis of variance and covariance according to the methods of Snedecor (19). The analysis of variance plan is presented in Table 2. Tests of significance for the F values with 1 degree of freedom each were made according to the method of Nair (17). Statements with reference to statistical significance are made at the 5 per cent level of probability.

RESULTS AND DISCUSSION

The main effects of rations fed, season and sex on average daily gain, efficiency of gain (as indicated by the average daily gain adjusted to the

TABLE 3.—EFFECT OF HIGH FIBRE RATIONS, PELLETED AND NON-PELLETED HIGH FIBRE-HIGH FAT RATIONS, SEASON AND SEX ON RATE OF GAIN AND FEED INTAKE OF BACON PIGS DURING THE GROWING, FINISHING AND TOTAL FEEDING PERIODS

Treatment Comparisons	No. of animals	Growing period			Finishing period			Total period		
		Av. daily gain		Av. daily feed	Av. daily gain		Av. daily feed	Av. daily gain		Av. daily feed
		Observed	Adjusted[1]		Observed	Adjusted[1]		Observed	Adjusted[1]	
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
General average	96	1.33	—	4.10	1.64	—	6.81	1.48	—	5.52
Control (1)[2]	24	1.43[a]	1.42[a]	4.19	1.74[a]	1.80[a]	6.51	1.59[a]	1.60[a]	5.41
High fibre (2) + (3) + (4)	72	1.30	1.30	4.07	1.60	1.58	6.91	1.45	1.45	5.55
High fibre, no fat (2)	24	1.27	1.28	4.05	1.50[b]	1.50[b]	6.82	1.38[b]	1.47	5.51
High fibre + fat (3) + (4)	48	1.31	1.32	4.07	1.65	1.62	6.96	1.48	1.38[b]	5.58
Non-pelleted (3)	24	1.31	1.33	3.91	1.57[c]	1.64	6.44[c]	1.44	1.47	5.28[c]
Pelleted (4)	24	1.32	1.31	4.23	1.73	1.60	7.48	1.52	1.48	5.87
Winter-finished	48	1.39[d]	1.36	4.37[d]	1.59	1.56[d]	6.99	1.49	1.46	5.80[d]
Summer-finished	48	1.27	1.30	3.83	1.69	1.72	6.64	1.48	1.52	5.24
Barrows	48	1.35	1.34	4.23[e]	1.70[e]	1.63	7.20[e]	1.53[e]	1.50	5.76[e]
Gilts	48	1.31	1.32	3.97	1.57	1.64	6.43	1.44	1.47	5.27

[1]Adjusted to equal feed intake by covariance technique
[2]Brackets indicate ration number

[a]Significantly higher than the high fibre rations
[b]Significantly lower than the high fibre + fat rations
[c]Significantly lower than the pelleted ration
[d]Significant from summer-finished pigs
[e]Significantly higher than gilts

average feed intake of the test) and feed consumption, during the growing, finishing and total feeding periods are shown in Table 3. No significant interactions were found for any of the response criteria studied.

Growing Period

The substitution of ground timothy-red clover hay for barley in the growing rations resulted in a significant decrease in rate and efficiency of gain. Jensen *et al.* (12) reported a decrease in growth rate when oat hulls were added to a corn-soybean oil meal ration. This was overcome by the addition of corn oil to equate the ration for T.D.N. Little response was obtained in the present experiment, from the introduction of stabilized tallow, to increase the calculated digestible energy of the high fibre growing ration to the level of the control diet. This is in accordance with the findings of Bowland and Berg (6), who have reported a small difference in gain in favour of pigs fed high energy rations during the growing period.

There was little difference in performance between pigs fed the pelleted high fibre-high fat ration and those fed the same ration non-pelleted.

Finishing Period

The replacement of part of the barley with ground timothy-red clover hay in the finishing rations resulted in a significant decrease in rate and efficiency of gain. The addition of tallow to this high fibre ration increased the rate and efficiency of gain. This indicates that digestible energy was a factor in depressing gains when the pigs were fed the high fibre rations, even though the addition of tallow to the high fibre rations did not increase rate of gain in the growing period.

There was no significant difference in daily feed consumption between pigs fed the high fibre ration and those fed the high fibre-high fat rations in either the growing or finishing periods. In contrast, Bowland and Berg (6) reported that pigs on high energy rations consumed more feed during the growing period but less feed during the finishing period than those on low energy rations. Pelleting the high fibre-high fat finishing ration resulted in gains equal to those for pigs fed the control ration. However, when the observed gains were adjusted to equal feed intakes, there was no significant difference in growth rate between pigs fed the pelleted and those fed the non-pelleted high fibre-high fat ration, indicating that the improved performance on the pelleted ration in the finishing period resulted from increased feed intake. This agrees with results reported by Esplin *et al.* (9) for fattening lambs fed pelleted and non-pelleted rations.

Total Period

The effects of fibre and fat on rate and efficiency of gain in the total feeding period were similar to those obtained in the finishing period. Pigs fed the high fibre-high fat pelleted rations consumed more feed per day over the total experimental period than those on the non-pelleted ration. This is in agreement with findings reported by Jensen *et al.* (13) who observed a trend toward increased daily feed consumption of pelleted rations above meal rations as the per cent of oats in the rations increased.

TABLE 4.—EFFECT OF HIGH FIBRE RATIONS, PELLETED AND NON-PELLETED HIGH FIBRE-HIGH FAT RATIONS, SEASON AND SEX ON CARCASS MEASUREMENTS AND GRADES

Treatment comparisons	No. of animals	Hot carcass weight	Dressing	Carcass length	Shoulder fat	Loin fat	Loin muscle area	Belly score	Total A.R. score	Carcass grades	
										A	B
		lb.	%	in.	in.	in.	sq. in.	(20 pts.)	%	%	%
General average	96	149.7	76.7	30.7	1.83	1.36	4.15	14.3	74.7	73	27
Control (1)[1]	24	153.5[a]	78.5[a]	30.5	1.92	1.43[a]	4.17	10.8[a]	67.3[a]	71	29
High fibre (2) + (3) + (4)	72	148.4	76.1	30.8	1.81	1.33	4.14	15.5	77.2	74	26
High fibre, no fat (2)	24	147.4	75.6	31.0	1.70[b]	1.26[b]	4.13	16.8	82.5	92	8
High fibre + fat (3) + (4)	48	148.9	76.3	30.7	1.86	1.37	4.15	14.8	74.5	65	35
Non-pelleted (3)	24	149.5	76.4	30.5	1.88	1.36	4.24	14.4	73.8	67	33
Pelleted (4)	24	148.3	76.3	30.8	1.84	1.37	4.06	15.3	75.3	63	37
Winter-finished	48	150.9[c]	77.1	30.8	1.81	1.34	4.27[c]	15.5	82.0[c]	81	19
Summer-finished	48	148.5	76.3	30.6	1.85	1.37	4.03	13.2	67.4	65	35
Barrows	48	150.6	77.1[d]	30.6	1.92[d]	1.41[d]	3.82[d]	13.2	67.2[d]	60	40
Gilts	48	148.8	76.3	30.8	1.75	1.30	4.48	15.5	82.3	85	15

[1]Brackets indicate ration number

[a]Significant from the high fibre rations
[b]Significantly lower than the high fibre + fat rations
[c]Significantly higher than summer-finished pigs
[d]Significant from gilts

There was no significant difference in rate of liveweight gain between pigs finished in winter and those finished in summer, over the total experimental period, although winter-finished pigs consumed 0.56 pound more feed, per animal per day, than those finished in summer.

Barrows consumed more feed per day, in all periods, and made significantly faster gains in the finishing period than female pigs. The small difference in gains (adjusted to equal feed intakes) observed between sexes, did not reflect the higher proportion of fat to lean in male carcasses, indicated by the depth of fat and loin muscle measurements. This apparently resulted from a reduction in length of feeding period for male pigs.

Lindahl and Reynolds (15) reported an increase in ether extract and decrease in crude fibre content of alfalfa meal as a result of the pelleting process. A similar effect on the crude fibre content of meal rations after pelleting was observed by Jensen *et al.* (13) and Larsen and Oldfield (14). These effects were not evident from pelleting the growing ration in the present experiment. However, the crude fibre content of the pelleted high fibre-high fat finishing ration, containing 25 per cent of ground timothy-red clover hay, was one percentage unit less than the same ration non-pelleted.

Carcass Characteristics

A summary of the main effects of the rations fed, season and sex on carcass measurements and commercial grades is presented in Table 4.

Substitution of ground timothy-red clover hay for part of the barley, in the control rations, resulted in decreased dressing percentage and depth of loin fat. A reduction in dressing percentage associated with a high fibre content in the ration has been observed by others (2, 5). As a consequence of the reduction in fat and increase in Advanced Registry belly score, there was a significant increase in total A.R. score. The addition of stabilized tallow to the high fibre rations resulted in increased carcass fat, and a marked reduction in the percentage of top grade carcasses. In contrast, Gesler *et al.* (10) and Clawson *et al.* (7), found little effect upon carcass measurements from the addition of 10 per cent of fat to the ration.

The improvement in carcass quality with the feeding of high fibre rations was accompanied by a decrease in rate of gain, while the adverse effect on carcass quality resulting from the addition of fat to the high fibre rations was associated with a significant increase in growth rate. However, when high fibre-high fat pelleted and non-pelleted rations are compared, the increased rate of gain obtained for the pelleted ration during the finishing period shows little effect on carcass characteristics or commercial grades. Thus, it would appear that growth rate is not necessarily associated with carcass quality, when different physical forms of the same ration are being compared.

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FISH VISCERAL FLOUR AS A SOURCE OF PROTEIN FOR GROWING-FINISHING BACON PIGS

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ABSTRACT

Two experiments, involving 144 individually-fed pigs, were conducted to determine the effects of fish visceral flour in growing and finishing rations on the performance and carcass characteristics of bacon pigs.

The most rapid average daily gains in this study were obtained from pigs fed mixtures of fish visceral flour and soybean meal. Pigs fed fish visceral flour as the only source of supplementary protein made slower gains in both experiments than those fed other rations.

Pigs fed high energy rations made more rapid gains in the finishing period and more efficient gains in the finishing and total feeding periods than those fed the control rations.

Level of fish visceral flour in the ration had no significant effect on carcass scores and grades. However, area of loin muscle decreased with increasing levels of fish visceral flour. High energy rations had an adverse effect on carcass measurements.

INTRODUCTION

Fish viscera (total viscera less livers) in commercial cod and haddock fishing is removed aboard ship and discarded. It is estimated that 135 million pounds of this waste material are available annually on the Atlantic coast of Canada. Its potential as a feed for livestock is not known. Freeman and Hoogland (7) reported that the approximate gross composition of this raw visceral material was as follows: "Moisture, 80%; protein (N x 6.25), 10 to 12%; fat, 1 to 2%; ash, 2 to 3%; and besides these growth constituents, it contains B-vitamins and possibly a number of unidentified growth factors". These workers conducted experiments to establish a suitable method of processing cod and haddock viscera and finally adopted a procedure which involved autolysis of the raw material in the presence of sodium nitrite, at a slightly elevated temperature and drying of the autolysate. Eighty-nine per cent of the nitrogen in the dried product was non-protein nitrogen in the form of amino acids and small peptides.

The two experiments reported herein were designed to study the effects on rate and efficiency of gain and carcass characteristics of bacon pigs of feeding growing and finishing rations containing fish visceral flour, prepared by the procedure outlined above. Since the palatability and feeding value of fish visceral flour (FVF) were initially unknown, it was fed as the entire supplementary protein in one ration in Experiment 1 in comparison with fish meal (FM), and soybean meal and tankage (S-T) in other rations. The effects of FVF in high energy (HE) rations and at varying levels in low energy rations on the performance and carcass measurements of market pigs were studied in Experiment 2. Rose *et al.* (11) reported that caloric intake must be significantly increased for a positive nitrogen balance when source of nitrogen is changed from an intact protein, to hydrolized protein, to free amino acids.

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TABLE 1.—PERCENTAGE COMPOSITION OF THE GROWING RATIONS FED IN EXPERIMENTS 1 AND 2

Ration description	Experiment 1			Experiment 2					
	Sources of protein			Levels of FVF (per cent in ration)				High energy (HE)	
	Fish visceral flour (FVF)	Fish meal (FM)	Soybean meal-tankage (S-T)	8.1	5.3	2.6	0.0 (Control)	Soybean meal-tankage (S-T)	Fish visceral flour-Soybean meal (FVF-S)
Ground barley (No. 1 feed)	76.1	76.1	71.3	76.7	75.4	74.0	71.8	53.1	55.4
Ground oats (No. 1 feed)	13.4	13.4	12.6	13.5	13.3	13.1	12.7	—	—
Ground wheat (No. 5)	—	—	—	—	—	—	—	20.4	21.3
Fish visceral flour	8.9	—	—	8.1	5.3	2.6	—	—	5.5
White-fish meal	—	8.9	—	—	—	—	—	—	—
Soybean meal	—	—	7.1	—	4.4	8.7	7.2	8.2	7.7
Tankage	—	—	7.1	—	—	—	7.2	9.0	—
Stabilized tallow	—	—	—	—	—	—	—	8.2	8.5
Ground limestone	0.5	0.5	0.8	0.9	0.9	0.9	0.4	0.4	0.9
Common ingredients[1]	1.2	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8
Crude protein (N x 6.25)[2]	17.0	16.9	16.9	16.6	16.6	16.6	17.0	17.0	16.9

[1]Vitamin B_{12} antibiotic supplement, 0.5 % in Experiment 1 and 0.1 % in Experiment 2, containing 1.8 and 10 gm. chlortetracycline hydrochloride per pound, respectively; iodized salt, 0.5%; feeding oil (1500A-300D), 0.2%.

[2]Calculated from values reported by Morrison (9) and protein analyses for fish visceral flour by Hoogland, Fisheries Research Board, Technological Station, Halifax, N.S. *Personal communication.*

TABLE 2.—RATE OF GAIN AND FEED INTAKE OF PIGS FOR THE GROWING, FINISHING AND TOTAL FEEDING PERIODS FOR EXPERIMENTS 1 AND 2

Treatment comparisons	No. of animals	Growing period			Finishing period			Total feeding period		
		Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
EXPERIMENT 1										
Average	48	1.22	3.60	2.97	1.34	5.64	4.23	1.28	4.71	3.69
FVF	16	1.16[a]	3.46[d]	2.98	1.29[b]	5.56[b]	4.32	1.23[c]	4.63[b]	3.77
FM	16	1.27	3.67	2.90	1.35	5.57	4.16	1.31	4.71	3.63
S-T	16	1.21	3.66	3.01	1.39	5.79	4.19	1.31	4.80	3.69
Summer-finished	24	1.24[e]	3.66	2.95	1.34	5.40[f]	4.08[f]	1.29	4.62[f]	3.58[f]
Winter-finished	24	1.19	3.54	2.99	1.35	5.88	4.38	1.27	4.80	3.81
Barrows	24	1.23	3.61	2.94	1.39[g]	5.72[g]	4.15	1.31[g]	4.75	3.63
Gilts	24	1.20	3.59	3.00	1.30	5.56	4.30	1.25	4.68	3.76
EXPERIMENT 2										
Average	96	1.39	4.29	3.12	1.72	6.55	3.84	1.55	5.45	3.53
Levels of FVF (Per cent in growing ration)										
8.1	16	1.30[a,b]	4.29	3.30	1.65[b]	6.47[c]	3.96	1.47[b]	5.41[b]	3.68
5.3	16	1.38	4.22	3.07	1.71	6.93	4.06	1.55	5.65	3.66
2.6	16	1.46	4.50	3.09	1.75	7.29	4.16	1.60	5.91	3.69
0.0 (Control)	16	1.38	4.37	3.18	1.64[d]	6.70[e]	4.10[e]	1.51	5.55[e]	3.69[e]
HE rations										
FVF-S	16	1.44	4.12	2.90	1.80	5.94	3.32	1.61	5.04	3.14
S-T	16	1.36	4.25	3.15	1.75	5.99	3.43	1.55	5.13	3.32
Summer-finished	48	1.45[f]	4.38[g]	3.05	1.67[g]	6.28[f]	3.78	1.56	5.39	3.46[g]
Winter-finished	48	1.33	4.20	3.19	1.76	6.83	3.90	1.54	5.51	3.60
Barrows	48	1.45[h]	4.44[h]	3.08	1.80[h]	6.88[h]	3.83	1.62[h]	5.67[h]	3.51
Gilts	48	1.32	4.14	3.15	1.63	6.23	3.85	1.48	5.22	3.55

EXPERIMENT 1

[a]Significantly lower than FM ration ($P<0.01$)
[b]Significantly lower than S-T ration ($P<0.05$)
[c,d]Significantly lower than FM and S-T rations, at levels of 0.01, and 0.05, respectively
[e,f]Significant from winter-finished pigs at levels of 0.05, and 0.01, respectively
[g]Significantly higher than gilts ($P<0.05$)

EXPERIMENT 2

[a]Linear effect of level of FVF significant ($P<0.05$)
[b,c]Quadratic effect of level of FVF significant, at levels of 0.05, and 0.01, respectively
[d,e]Significantly lower ($P<0.05$), and higher ($P<0.01$) than combined HE rations, respectively
[f,g]Significant from winter-finished pigs at levels of 0.01, and 0.05, respectively
[h]Significantly higher than gilts ($P<0.01$)

MATERIALS AND METHODS

Design of the Experiments

A completely randomized design was used in each experiment. In Experiment 1, the treatments were arranged in a 2 x 2 x 3 factorial design. The three factors involved were: winter versus summer farrow; barrow versus gilt; and three ration combinations. Four pigs were used in each of the 12 treatment combinations giving a total of forty-eight experimental animals. In Experiment 2, the treatments were arranged in a 2 x 2 x 6 factorial design with the same factors of season and sex as in Experiment 1 and six ration combinations. Four pigs were used in each of the 24 treatment combinations, giving a total of ninety-six experimental animals.

Rations

The percentage composition of the growing rations fed in the two experiments is shown in Table 1.

During the growing period (35 ± 5 to 105 ± 5 pounds) all pigs received a ration containing a calculated level of about 17 per cent crude protein. The same rations were fed during the finishing period (105 ± 5 pounds to the market weight of 200 ± 10 pounds) except that the level of protein was reduced to 14 per cent, and oats increased to 30 per cent of the grain mixture at the expense of barley.

The moisture, fat, ash, crude fibre and total nitrogen content of the fish visceral flour was 5, 7, 11.5, 0.2 and 10.4 per cent, respectively*.

Animals

The pigs used were purebred Yorkshires, raised at the Experimental Farm, Nappan, Nova Scotia. All pigs were by the same sire and from litter mate sows. The male pigs were castrated at 2 weeks of age. All pigs were weaned at 8 weeks of age and started on experiment at a weight of 35 ± 5 pounds. The pigs were penned individually on concrete floors in a heated experimental piggery. All animals were individually hand fed three times daily during the growing period and twice daily during the finishing period in amounts limited by appetite. Each animal had free access to individual automatic waterers. Individual weights of the pigs and their feed consumption were recorded bi-weekly. Carcass measurements and scores were obtained under Canadian Advanced Registry for Swine standards (2). Commercial grades were obtained on all carcasses.

The data from each experiment were subjected to analysis of variance according to the methods of Snedecor (13).

RESULTS AND DISCUSSION

A summary of data on rate of gain, feed consumption and efficiency of feed utilization for Experiments 1 and 2 is presented in Table 2. The mean carcass data from both experiments are shown in Table 3.

Rate of Gain, Feed Consumption and Efficiency of Feed Utilization

Pigs fed the FVF ration in Experiment 1 made slower gains and consumed less feed per day than those fed the FM or S-T rations. Statistical

*Hoogland, P. L. Fisheries Research Board, Technological Station, Halifax, N.S. *Personal communication.*

TABLE 3.—SUMMARY OF SLAUGHTER DATA, CARCASS MEASUREMENTS AND GRADES — EXPERIMENTS 1 AND 2

Treatment comparisons	No. of animals	Hot carcass weight	Dressing	Carcass length	Shoulder fat	Back fat	Loin fat	Loin muscle area	Belly score	Total A.R. score	Carcass grades			
											A	B	C	B_3
		lb.	%	in.	in.	in.	in.	sq. in.	(20 points)	%	%	%	%	%
EXPERIMENT 1														
Average	48	153.4	78.4	30.9	1.74	0.77	1.25	4.00	17.1	86.1	96	4	—	—
FVF	16	152.9	77.9[a]	31.0	1.74	0.79[a]	1.24	3.87[a]	16.9	85.4	100	—	—	—
FM	16	153.9	79.1	30.7	1.68	0.72	1.24	4.09	16.7	84.7	94	6	—	—
S-T	16	153.4	78.1	31.0	1.79	0.81[a]	1.26	4.03	17.7	88.1	94	6	—	—
Summer-finished	24	153.4	78.5	31.0[b]	1.74	0.78	1.25	4.13[c]	17.5	87.6	100	—	—	—
Winter-finished	24	153.4	78.3	30.7	1.74	0.77	1.24	3.86	16.7	84.5	92	8	—	—
Barrows	24	153.3	78.4	30.8	1.77	0.80	1.29[d]	3.79[e]	16.5	82.0[e]	92	8	—	—
Gilts	24	153.5	78.3	31.0	1.70	0.75	1.20	4.20	17.7	90.2	100	—	—	—
EXPERIMENT 2														
Average	96	154.8	78.9	30.7	1.95	0.94	1.47	3.94	13.4	72.7	59	33	7	1
Levels of FVF (% in growing ration)														
8.1	16	153.7	77.5[a]	30.9	1.88	0.91	1.39	3.84[b]	15.1	79.0	81	19	—	—
5.3	16	155.4	79.0	30.9	1.95	0.91	1.46	3.98	14.4	76.9	69	31	—	—
2.6	16	152.9	78.4	30.7	1.91	0.90	1.39	3.95	13.9	75.4	69	25	6	—
0.0	16	152.6[c]	78.4[c]	30.5	1.87[c]	0.90[c]	1.39[c]	4.14[d]	15.7[c]	76.9[c]	69	25	6	—
HE rations														
FVF-S	16	157.3	80.6[e]	30.3	2.11[e]	1.09[f]	1.71[f]	3.76	8.6[e]	54.4[f]	6	63	31	—
S-T	16	157.1	79.6	30.7	1.96	0.94	1.47	3.96	12.9	73.3	57	37	—	6
Summer-finished	48	154.7	79.1	30.6	1.97	0.96	1.49	3.97	13.4	72.6	59	31	10	—
Winter-finished	48	154.9	78.8	30.7	1.93	0.93	1.45	3.89	13.5	72.7	58	35	4	2
Barrows	48	154.9	79.2[g]	30.4[h]	2.03[h]	1.01[h]	1.55[h]	3.68[h]	10.4[h]	61.8[h]	42	46	12	—
Gilts	48	154.7	78.6	31.0	1.87	0.87	1.39	4.20	16.5	83.5	76	20	2	2

EXPERIMENT 1

[a] Significant from FM rations ($P<0.05$)
[b,c] Significantly higher than winter-finished pigs at levels of 0.05, and 0.01, respectively
[d, e] Significant from gilts at levels of 0.05, and 0.01, respectively

EXPERIMENT 2

[a] Quadratic effect of level of FVF significant ($P<0.05$)
[b] Linear effect of level of FVF significant ($P<0.05$)
[c,d] Significant from combined HE rations at levels of 0.01, and 0.05, respectively
[e,f] Significant from S-T rations at levels of 0.05, and 0.01, respectively
[g,h] Significant from gilts at levels of 0.05, and 0.01, respectively

analysis of the feed efficiency data failed to show any significant difference ($P < 0.5$) in feed efficiency between ration treatments. There was no evidence of toxicity from the feeding of FVF rations. These results indicated that the slower gains for pigs fed rations containing fish visceral flour than those fed other rations were related to a lower feed intake.

In Experiment 2, rate of gain decreased linearly with increasing levels of fish visceral flour in the growing ration. Level of FVF had a significant effect on growth rate, in all periods, and on feed intake in the finishing and total feeding periods, as measured by the quadratic regression. A statistical analysis of the feed efficiency data indicated that level of FVF in the ration had no significant effect on feed conversion. These results confirmed the findings in Experiment 1, and indicated that feed intake was the major factor that influenced the performance of the pigs.

The reasons for the decrease in feed consumption as the level of FVF was increased in the ration are not readily apparent. It may have resulted from the high content of hydrolized protein in fish visceral flour. The odour of fish visceral flour was similar to that of fish meal and did not appear to be objectionable to the pigs. During the first 2 weeks on experiment, the average daily feed consumption for the pigs fed rations containing 8.1 and 5.3 per cent of fish visceral flour was essentially the same as for those on the control ration, and slightly lower than those fed the 2.6 per cent FVF ration. As suggested by the recent research of Acker *et al.* (1), it is possible that lysine may have been a factor. In their work a significant linear decrease in feed intake was obtained with growing pigs, as supplemental levels of L-lysine were increased from 0 to 0.5 per cent. The calculated lysine content of the ration containing 8.1 per cent of FVF in this experiment was 0.98 per cent, based upon N.R.C. values (10) and the value for fish visceral flour by Hoogland*. This is in excess of the 0.63 per cent level suggested as adequate by Becker *et al.* (3), and the 0.62 per cent requirement suggested by Meade and Teter (8) for growing pigs.

Pigs fed high energy rations made faster gains in the finishing period and more efficient gains in the finishing and total feeding periods than those on the control diet. Similar results were obtained when 5 per cent of stabilized tallow replaced barley in high fibre rations (6). In the finishing and total periods, pigs fed HE rations consumed less feed per day than those on the control rations. This inverse relationship of available energy content of the ration with feed intake was also observed by Bowland and Berg (4) in the finishing period.

On the high energy rations, the pigs fed the FVF-S rations made a greater growth response on a smaller feed intake than those fed the S-T rations. However, this difference did not approach significance.

Summer-finished pigs made more rapid gains in the growing period, in both experiments, and slower gains in the finishing period, in Experiment 2 than those finished in winter. The reverse situation in the growing period was observed in a later trial with high fibre rations (6). Feed

*Hoogland, P. L. Fisheries Research Board, Technological Station, Halifax, N.S. *Personal communication.*

consumption per day was lower for summer-finished pigs in the finishing and total periods in Experiment 1 and higher in the growing and lower in the finishing periods in Experiment 2, than those finished in winter. Pigs finished during the summer required less feed per pound of gain in the finishing period in Experiment 1 and in the total feeding period in both experiments.

In Experiment 1, barrows made more rapid gains in the finishing and total periods and consumed more feed per day in the finishing period than gilts whereas, in Experiment 2, males made faster gains and consumed more feed per day, in all periods, than female pigs. This is reflected in a higher proportion of fat to lean in male carcasses. Faster gains for male than female pigs has also been reported by others (4, 14). There was no statistically significant difference in efficiency of feed utilization between sexes in either experiment. In contrast, Bowland and Berg (4) reported that females required less feed per pound of gain than male pigs during the finishing period.

A significant season x sex interaction occurred in rate of gain for the total period in Experiment 1, and for daily feed consumption in the finishing and total periods in Experiment 2. Examination of average responses shows that males made faster gains than females, in the total period in Experiment 1, and consumed more feed per day in the finishing and total periods in Experiment 2, for pigs finished in summer, while little difference in these responses between sexes occurred for pigs finished in winter. A significant sex x FVF_Q (quadratic effect of the level of FVF) interaction for average daily gain in the finishing period, in Experiment 2, indicated a greater decrease in rate of gain for females at the higher levels of FVF than for male pigs. A significant season x FVF_Q interaction for feed required per pound of gain in the finishing period, in Experiment 2, indicated a greater decrease in feed consumption per pound of gain at the higher levels of FVF, for pigs finished in winter than for those finished in summer.

A taste panel test of meat from pigs on each of the ration treatments, in Experiment 1, was conducted by Seaman (12), who reported no consistent effect of ration treatment on the acceptability of the pork; however, she did not consider the results conclusive.

Carcass Characteristics

Carcasses from pigs fed FVF rations in Experiment 1 had a lower dressing percentage, greater back fat thickness and a smaller area of loin muscle than pigs fed FM rations. However, the differences in carcass measurements were not reflected in total carcass scores or grades. There was little difference between pigs fed FVF rations and those on S-T rations in any of the carcass measurements studied, although pigs fed FVF rations made significantly slower gains than those on other rations.

In Experiment 2, level of FVF significantly affected the area of loin muscle as measured by the linear regression, and dressing percentage as measured by the quadratic regression. The area of loin muscle in carcasses from pigs fed fish visceral flour as the only supplementary protein was smaller than those on any other dietary treatment in both experiments.

This is of interest in light of the high percentage of enzymatically hydrolized protein in the FVF rations, and recent evidence reported by Brooks and Thomas (5) indicating that quality of protein in the ration affected the muscling in carcasses of pigs. Carcasses from pigs fed HE rations had a higher dressing percentage than those from pigs fed control rations. This was expected since carcasses from pigs fed HE rations were fatter than those on the control diet. The HE rations had an adverse effect upon all carcass measurements with the exception of carcass length. Carcasses from pigs fed FVF-S rations had a higher dressing percentage and depth of fat, and lower Advanced Registry belly and total scores than those from pigs fed S-T rations. This may have resulted from a higher level of fat in FVF-S rations and slightly faster gains for pigs fed these rations than those fed S-T rations.

The larger loin muscle area observed for summer-finished pigs in Experiment 1 may be associated with a significantly greater carcass length for these pigs than those finished in winter. Season had no statistically significant effect on any of the carcass characteristics in Experiment 2. Barrows had a higher fat-to-lean ratio than gilts in both experiments. This is probably a reflection of the more rapid rate of gain for male than female pigs.

A season x FVF_q interaction in hot carcass weight in Experiment 2 indicated a greater decrease in this measurement at the higher levels of FVF for pigs finished in summer than those finished in winter.

The above results would indicate that fish visceral flour may be used to advantage as a source of supplementary protein in basal rations of barley and oats for growing-finishing bacon pigs. However, the most rapid gains in this study were obtained from pigs fed mixtures of fish visceral flour and soybean oil meal.

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CHANGES IN THE GROSS CHEMICAL COMPOSITION OF THE MOUSE DURING GROWTH IN RELATION TO THE ASSESSMENT OF PHYSIOLOGICAL AGE[1]

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ABSTRACT

The body composition of 111 male white mice in terms of protein, water, fat and ash was determined. On the average, the protein, water and ash fractions appeared to exhibit differential growth with respect to the body weight and to the fat-free weight. The concentration of fat in the body was extremely variable and presumably reflected nutritive condition. The regularity of the average changes in the composition of the fat-free body appeared to be a fundamental property of the growth of mice, the percentage of water decreasing and of protein and ash increasing as growth proceeds. A new index of physiological age, the protein to water ratio, is suggested and evidence for its usefulness is presented.

INTRODUCTION

Attempts to improve the efficiency of meat production require a basic understanding of the nature of the growth processes. It cannot involve only a consideration of the kinetics or time rate of mass increase but must also include a consideration of other aspects of growth such as feed efficiency, body composition and metabolic rate. This is so because changes in any one of these induces parallel changes in each of the others as growth proceeds. Differences in the rate and efficiency with which animals grow may occur between individuals of the same species and even between individuals in a single litter in the multiparous species (16). It is probable that these differences are largely the result of variations in the relative amounts of the ingested nutrients which are distributed between the maintenance energy cost and the energy content of the gain. It is unreasonable that they could be due to variations in the net energetic efficiency of the individual animals. The exact composition of the gain at the various stages of growth depends on the relative priority of the various tissues for available nutrients at each of these stages (15). Thus, the chemical nature of the gain and the absolute amount of the gain will depend on the stage of growth as well as the plane of nutrition.

Because of the inherent difficulties associated with the determination of metabolic rate and body composition in large domestic animals, the house mouse (*Mus musculus*) was selected as the animal of choice for the present study. It was hoped that basic facts established with the mouse might be extrapolated to and ultimately confirmed with smaller numbers of one of the domestic species. A series of experiments were undertaken to delineate the nature of the average changes in body composition and metabolic rate during growth and to examine the relationship between these findings and variations of growth rate and feed efficiency in animals subjected to different planes of nutrition during the growing phase.

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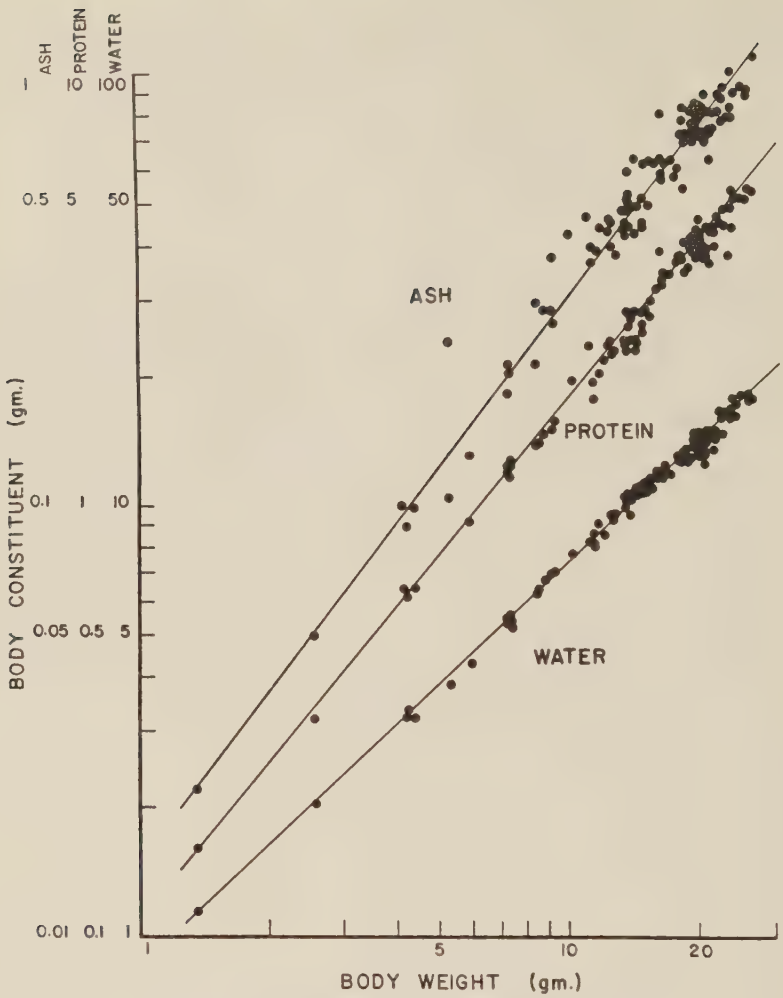

FIGURE 1. Body weight–Body constituent relationship.

The present paper records the body composition data from mice reared on a high plane of nutrition and attempts to describe the changes of body composition in terms of an index of physiological age. Subsequent reports will deal with the changes in metabolic rate that accompany the sequential changes in body composition and with the effect of plane of nutrition on these changes.

MATERIALS AND METHODS

One hundred and eleven male, U.B.C. strain Swiss Albino mice, ranging in age from birth to 118 days, were submitted to basal metabolic rate determination, then killed and submitted to analyses for fat, protein, water and ash. In all cases, with the exception of the very young mice, weighing less than 6 grams, each animal was analysed separately. For the young mice from four to six litter-mate males were analysed as a group at each body weight.

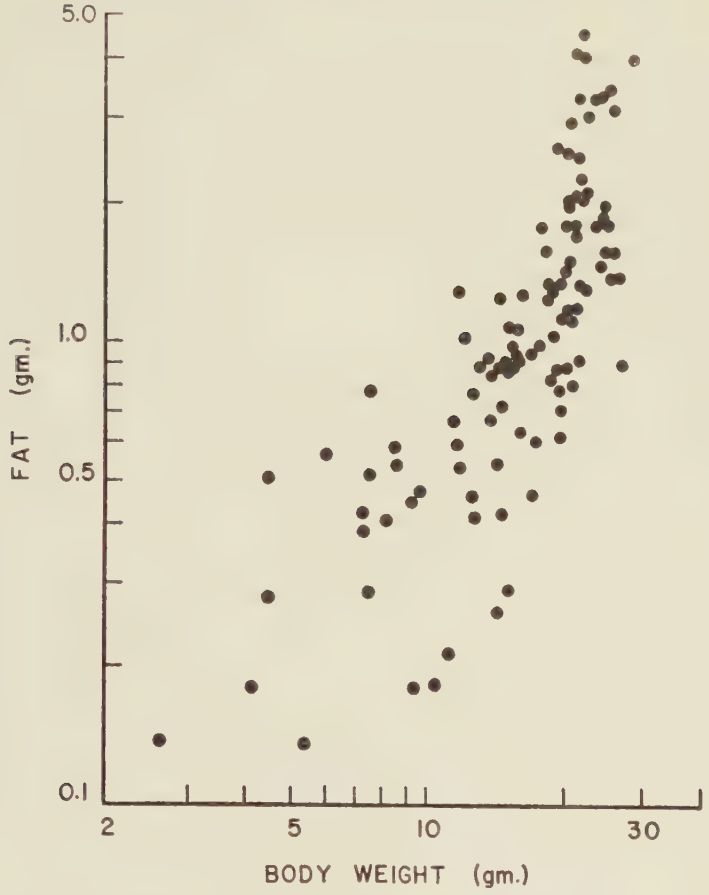

FIGURE 2. Body weight—Body fat relationship.

After an overnight fast, the animal was killed by a sharp blow on the head, its three body cavities were opened, and the whole carcass was dried to constant weight in an oven maintained at 105°C. The digestive tract was empty except in the case of the very young mice. The weight loss was recorded as the total body water content. The dried carcass was ground in a mortar and then transferred quantitatively to a small flask. The ether extractives were removed by repeated shaking of this residue with several aliquots of ethyl ether. Each extraction was followed by decantation through filter paper. The fat-free, moisture-free residue was analysed for ash and total nitrogen by standard methods. The protein was expressed as the total nitrogen of the fat-free body multiplied by 6.25.

RESULTS

The data on the amounts of body water, protein and ash in the bodies of the mice are represented in the form of a log-log relationship (Figure 1). This means of expression was chosen because the results appeared to follow best the differential growth form (4, 9). The logarithms of the weights

TABLE 1.—EQUATIONS, CORRELATION COEFFICIENTS, AND STANDARD ERRORS OF ESTIMATE OF THE LINES IN FIGURES 1, 3 AND 4[1]

X	Y	Equation	Figures	r	Standard errors of estimate	
					+	−
Body weight	Water	$Y = 0.880 \times 0.913$	1	0.997	3.5	3.4
Body weight	Protein	$Y = 0.117 \times 1.16$	1	0.991	8.0	7.4
Body weight	Ash	$Y = 0.0190 \times 1.21$	1	0.979	13.4	11.8
Fat-free body weight	Water	$Y = 0.878 \times 0.941$	3	0.999	2.2	2.2
Fat-free body weight	Protein	$Y = 0.116 \times 1.20$	3	0.995	6.1	5.7
Fat-free body weight	Ash	$Y = 0.0187 \times 1.25$	3	0.984	11.2	10.5
Water	Protein	$Y = 0.139 \times 1.27$	4	0.990	8.6	7.9
Protein	Ash	$Y = 0.177 \times 1.04$	4	0.989	9.7	8.9

[1]Ezekiel, M. Methods of correlation analysis. John Wiley & Sons, New York, N.Y. 1941.

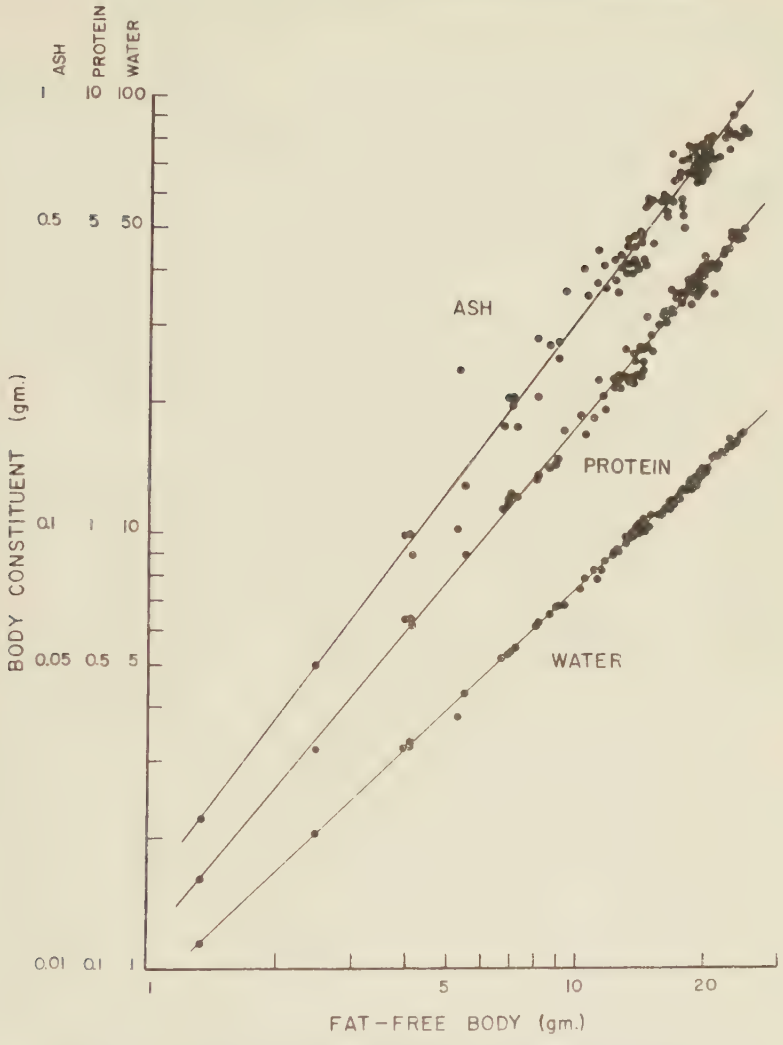

FIGURE 3. Fat-free body weight–Body constituent relationship.

of water, protein and ash were highly correlated with the logarithm of body weight (Table 1). On the average, a unit increase in body weight was accompanied by greater than unit increases in protein and ash and less than unit increases in water. The equations which were fitted to the data appear in Table 1.

The log-log relationship between body fat and body weight (Figure 2) was much less uniform than those for the three other chemical components of the body. This result was not unexpected for large variations in body fat content may occur as a result of differences in the previous nutritional history of the animals. Because of the variations in body fat, changes in the body composition of the mice on the basis of the fat-free body mass are represented, according to the differential growth form, in Figure 3.

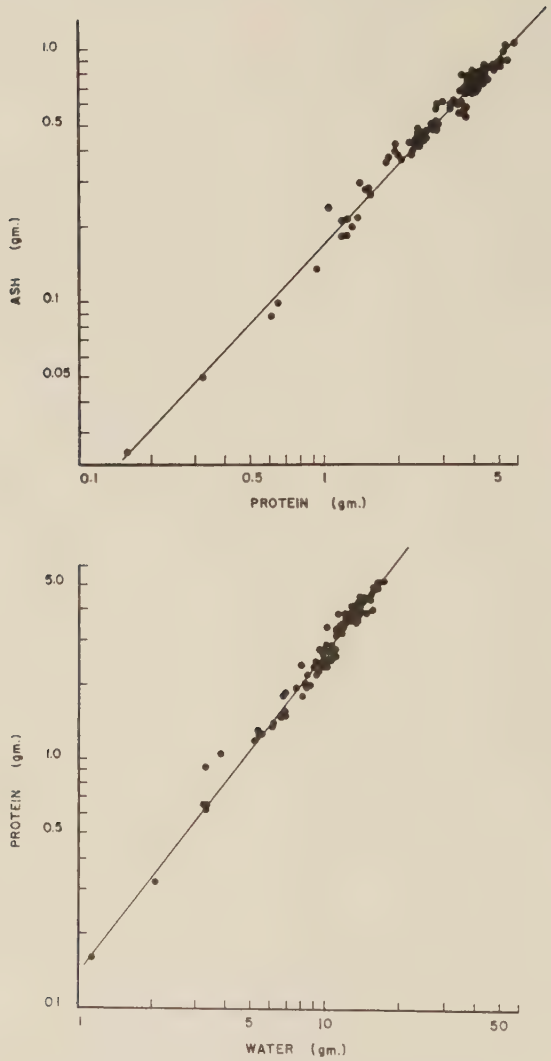

FIGURE 4. Body protein—Body ash and Body water—Body protein relationships.

As would be expected the slopes of the lines were of the same order as those obtained on the basis of the entire body mass (Table 1). The standard errors were, however, smaller when the composition was expressed on the fat-free body weight basis.

The changing relationships between the components of the fat-free mass were considered of interest. Figure 4 shows the log-log relationships between body water and body protein and between body protein and body ash. The equations for these lines are given in Table 1. The slope of the protein-ash line approached unity (1.04) which agrees with the general finding of Murray (18) that the ratio of ash to protein in the animal body

TABLE 2.—BODY COMPOSITION DATA FOR 16 SELECTED MICE

Mouse	Body weight (gm.)	Fat-free body weight (gm.)	Age (days)	Body fat (%)	Weight of constituent (gm.)			Per cent of fat-free body weight			Protein / Water	Ash / Protein
					Water	Protein	Ash	Water	Protein	Ash		
1	1.37	1.34	0	2.2	1.14	0.16	0.03	85.1	11.9	2.3	0.142	0.187
2	2.59	2.45	4	5.4	2.05	0.32	0.05	83.7	13.1	2.0	0.156	0.156
3	4.23	4.05	10	6.4	3.28	0.64	0.10	81.0	15.8	2.5	0.195	0.156
4	5.37	5.24	50	2.4	3.84	1.03	0.24	73.3	19.7	4.6	0.268	0.233
5	6.02	5.45	12	9.5	4.33	0.91	0.13	79.5	16.7	2.4	0.210	0.143
6	7.49	6.97	17	6.9	5.42	1.26	0.20	77.8	18.1	2.9	0.233	0.159
7	9.33	8.88	20	4.8	6.95	1.48	0.28	78.2	16.7	3.2	0.214	0.189
8	12.88	12.13	22	5.8	9.18	2.31	0.44	75.7	19.0	3.6	0.252	0.190
9	14.11	13.85	31	1.8	10.32	2.78	0.58	74.6	20.1	4.2	0.269	0.208
10	16.31	15.37	45	3.9	11.38	3.11	0.60	74.0	20.2	3.9	0.274	0.193
11	18.61	17.01	61	8.6	12.39	3.69	0.70	72.8	21.7	4.1	0.298	0.190
12	19.66	18.78	48	4.5	12.61	4.07	0.72	67.2	21.7	3.8	0.322	0.177
13	20.53	17.56	69	14.5	12.87	3.72	0.75	73.3	21.2	4.3	0.289	0.201
14	22.15	19.84	97	10.4	14.53	4.24	0.78	73.3	21.3	3.9	0.291	0.184
15	24.34	22.43	59	7.8	16.50	4.70	0.80	73.6	20.9	3.6	0.285	0.170
16	26.94	24.38	45	9.5	17.83	5.24	0.88	73.3	21.5	3.6	0.294	0.168

changes but little. The slope of the water-protein relationship was greater than unity (1.27) showing that the ratio of protein to water increased with increasing weight, though at a decreasing rate.

The above results demonstrate that, on the average, the composition of the dry non-fat portion of the body remained relatively constant with increasing body weight, that the hydration of the ash-protein fraction uniformly decreased, and that the amount of fat present exhibited great variation throughout all stages of growth. To further illustrate these findings, data for a selection of 16 animals covering a body weight range from 1.37 to 26.94 grams are given in Table 2.

DISCUSSION

Body Composition

The concept of differential growth has been shown to apply to the growth of various anatomical parts, tissues, and organs and a variety of linear dimensions in many different species (4, 8, 15, 20, 21). The present results show that, on the average, the gross chemical components of the body of the mouse also exhibited differential growth. It follows that these changes would be in the same direction in individual mice and, under conditions of optimum nutrition, would have the same general form. In other words, growth in individual animals would be accompanied by a decrease in the percentage of water and an increase in the percentage of protein and ash in the fat-free body.

Murray (18) and Moulton (17) recognized that large variations occur in the fat content of animal bodies due to changes of nutritive state and the latter (17) proposed that the chemical composition be compared on a non-fat basis. Brozek (5) has reiterated this view. The data in the present paper confirm the validity of this approach. Moulton (17) also observed that the composition of the fat-free body changed in a characteristic manner with age. Beyond a certain age for each species, which he termed the point of "chemical maturity", there were no further changes in the chemical composition of the fat-free body. The mature proportions of water, protein, and ash were apparently unaffected by degree of fatness (2, 3, 17) or nutritive state (7, 17). Recalculation of data given by Alonso and Maren (1) shows that there was no difference in the average percentage of water in the fat-free bodies of genetically obese mice and their lean siblings. The "chemically mature" proportions of our mice, based on the percentage of water in the fat-free body, were reached at an age of 55 to 60 days (Figure 5). The water content at this age was about 72.8 per cent. This compares with an average value of 73.2 per cent derived from data for adult animals of the rat, guinea-pig, rabbit, cat, dog and monkey (19). Moreover, values of 72.6, 74.4 and 73.2 per cent were obtained for the adult cow (11), pig (12), and human (22) respectively.

Increases in the weight of the fat-free body were always accompanied by changes in the proportions of the constituents of the fat-free body (Figure 3, Table 2). Since no changes occurred in the proportions of water, protein or ash in the fat-free body of our mice at ages greater than

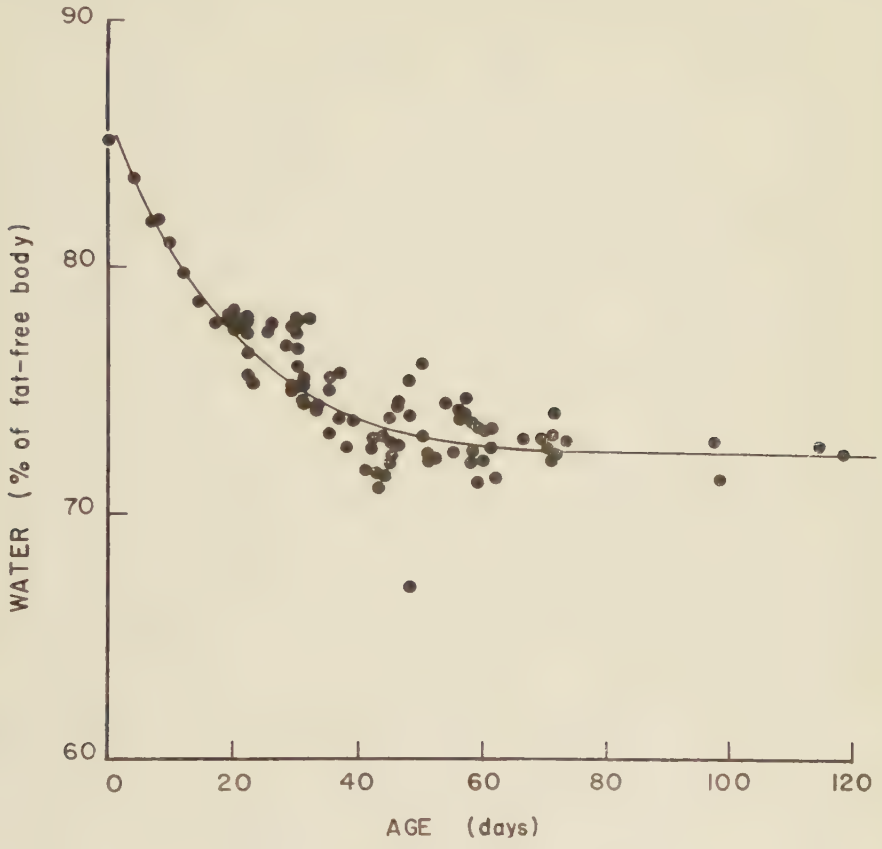

FIGURE 5. Age—Body water relationship.

that at which chemical maturity was attained (older than 55 to 60 days in the case of this mouse strain), it follows that the attainment of mature fat-free body size coincides with the attainment of chemical maturity. This implies that increases of total body weight which occur after chemical maturity has been reached must be largely gain in fat. Utilizing the value for the water percentage of the fat-free body (72.8 per cent), the chemical composition of the average mature mouse of the strain used in the present study was calculated from the equations given in Table 1. This information appears in Table 3.

Physiological Age

It would be useful to compare the physiological status of individual animals within a species not only at equivalent physiological states such as puberty or chemical maturity but at any point during the growing phase. The inadequacy of body weight or chronological age as indices of physiological status is apparent in the light of the fact that the relationship between these two variables may be so drastically altered by nutritional means. The

TABLE 3.—BODY COMPOSITION DATA FOR THE AVERAGE MATURE INDIVIDUAL OF THE STRAIN OF MICE USED IN THE PRESENT STUDY COMPUTED FROM EQUATIONS IN TABLE I

Characteristic	Value
Age	55–60 days
Body weight	26.3 gm.
Fat-free body weight	23.9 gm.
Body water	17.4 gm.
Body protein	5.2 gm.
Body ash	0.99 gm.
Body fat	2.4 gm.
Protein/water	0.299
Ash/protein	0.190
Body water—per cent of fat-free body	72.8 per cent

rate of passage of physiological events or, in other words, the rate of physiological aging is not synchronous with the passage of sidereal time. A unit of time measured by the clock has a very different physiological significance for short-lived than for long-lived animals and, within a given individual, physiological events happen in a much shorter time in the young than in the aged (6). If a simple method could be found for estimating the physiological age of animals, it would be possible to utilize this measure for the comparison of different individuals.

Carrel (6) has listed two methods for the assessment of physiological age. These are (a) the rate of healing of a wound and (b) the ability of serum to inhibit the growth of pure cultures of fibroblasts. The results of the present work suggest that, since changes in the composition of the fat-free portion of the body accompanied the growth process, an expression of these changes might serve as an index of the physiological age. Perhaps the best expression would be the ratio of protein to water because, as Keys and Brozek (10) suggested, the living, metabolizing mass may be considered to be a mixture of water and protein. The data in Figure 6 show that the ratio of protein to water tended to increase with weight and age though at a decreasing rate. This characteristic should be a property of any index of physiological age (6).

The usefulness of the protein to water ratio in distinguishing between animals of the same weight or age is illustrated by the data in Table 2. Thus, mice 4 and 12 were nearly the same age but the latter was heavier and physiologically more mature on the basis of the protein to water ratio. On the other hand, mice 4 and 5 weighed about the same but the former was both chronologically and physiologically older. The weight and the physiological age of mouse 4 were both less than the average for 50-day-old mice. The average physiological age (in terms of the protein to water ratio) for a mouse of this chronological age would be 0.293 as compared with the actual value of 0.268. On the other hand, the average body weight of a mouse with protein to water ratio of 0.268 was 16.6 grams, which contrasts markedly with the value actually found for this animal of 5.37 grams. It would appear that the growth of mouse 4 had been retarded,

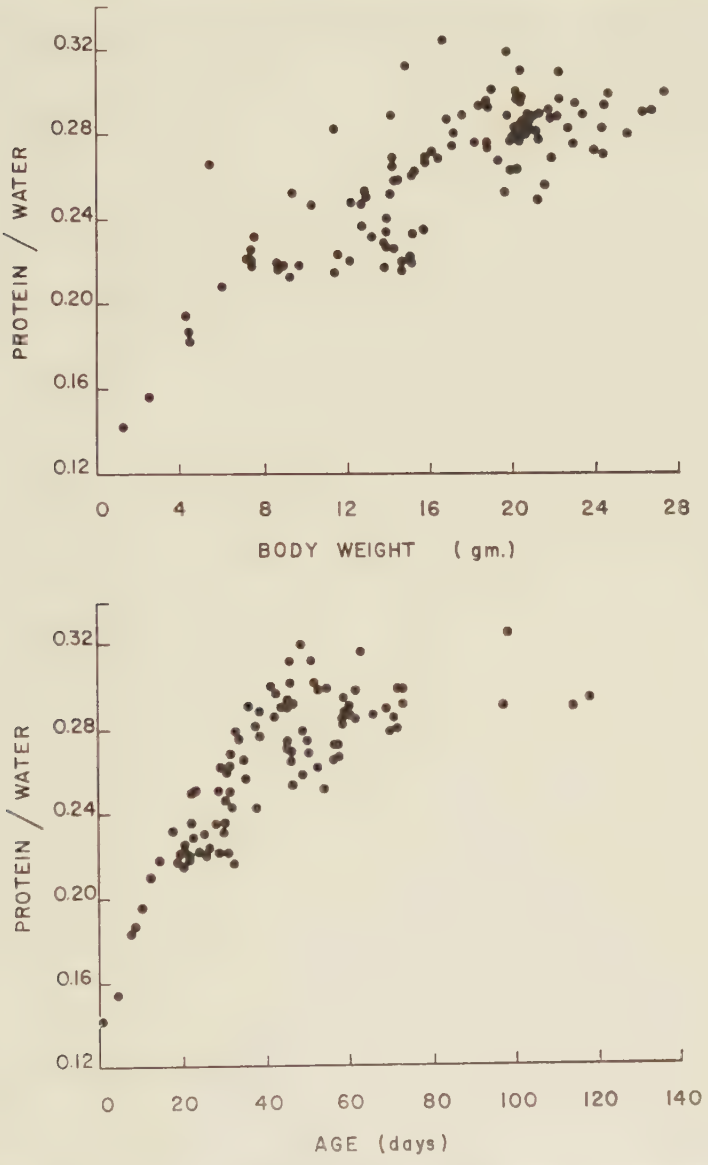

FIGURE 6. The relationships between the age and the weight of the mice and the ratio of protein to water in their bodies.

probably because it was from a large litter and may not have received enough milk. Its rate of physiological aging had also been retarded though not to the same extent.

The above example illustrates that a mouse which is old according to its weight or age may be physiologically young and vice versa. Differences in the relationship between weight-age data and physiological age may be a

function of the previous nutritional history of the animals. Thus, there are indications that physiological aging may be postponed by restricted nutrition (13, 14). In addition, results to be presented in a subsequent paper in this series show that retardation of growth in mice by caloric restriction retarded the rate of change of the protein to water ratio as measured by comparison with non-restricted animals. It may be supposed, therefore, that nutrient restriction, in addition to slowing growth rate, also retards physiological aging and hence prolongs the time of approach to maturity.

There are at present no reliable techniques for the *in vivo* estimation of the composition of the animal body. When such techniques become available, extrapolation of the present findings to the common meat-producing animals would be of considerable assistance in the study of nutrition and breeding. Two animals of equal age or weight but of differing physiological age would be expected to differ in their nutritional requirements. Some of the animal to animal variation in vitamin and amino acid requirements at a common age and body weight may well be explicable on the basis of differences in their physiological ages (23). Data to be presented in a later paper will show that the previous nutritional history of an animal can markedly affect its subsequent body composition and hence the improvement of animals by many of the criteria of selection used at present would presumably be most difficult.

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SUGGESTIONS FOR PRESENTATION OF STATISTICS IN CONTRIBUTIONS TO THE "CANADIAN JOURNAL OF ANIMAL SCIENCE"

As Prepared by a Committee appointed by the Canadian Society of Animal Production

1. The purpose of statistical methods in research is to aid in making the most meaningful interpretation possible of the experimental data and to provide a measure of confidence (fallability) in the conclusions.
2. Authors should describe the experimental design or sampling procedure in sufficient detail to allow the reader to determine exactly how the investigation was set up.
3. A precise résumé of the procedures employed in the analysis of the data should be given. This *may not* require the presentation of a table of the analysis procedure but perhaps more information than title and author of a reference should be given. *If* an analysis of variance table is presented, it should include degrees of freedom, mean squares, and expected mean squares, when applicable.
4. Presentation of an excessive amount of data should be avoided. All averages pertinent to the correct interpretation of the results should be presented.
5. Attention needs to be drawn only to points important to the argument being developed. There is no point in repeating in the text of a paper the information which may be obtained from a table or graph that is included.
6. A measure of variability (reliability) of the means should be given. Points to be considered are:
   (1) The standard error is by far the best technique. From the various standard errors, it is possible to calculate any of the other measures of reliability. Unless it is obvious (and perhaps even then), the number of degrees of freedom should be indicated.
   (ii) It should be made clear what mean $\pm a$ represents. Too frequently the reader is not advised whether the statistic a measures the variability associated with a single item or a mean, or represents a confidence interval.
   (iii) The least significant difference (L.S.D.). The general use of this statistic is to be discouraged since it is so often wrongly employed. The insertion of "N.S." (non-significant) where the effects fail to reach significance is most undesirable.
   (iv) The coefficient of variation, although useful when used properly, can be meaningless.
7. Where there are two or more sources of experimental error, estimates of all error terms should be presented. These circumstances arise under conditions of random effects, split-plot design, stratified sampling, etc.
8. The frequency of the use of the word "significant" should be kept to a minimum. It is usually worked to death in scientific papers. All statements of significance should be accompanied by a statement of the level of probability used. Results that just fail to reach "significance" at the usual level of probability should not be ignored.

9. Emphasis should be placed on the comparisons of interest and not on the tests of significance that were made. This will lead naturally to the necessary practical interpretation of the results.
10. Authors should confine "speculation" to the section entitled "Discussion" as much as possible.
11. In correlation studies vigilance should be exercised to guard against overconfidence in interpretation of coefficients. Particular care should be taken when the number of degrees of freedom is large.
12. Interpretation of correlations and regressions of variables related as ratios or as a part and the whole should be done with extra caution.
13. If a transformation of data is necessary, then in general it is better to reconvert back to the original units, if feasible, for presentation.
14. In general there is no need to use more than three significant digits in presenting results.

Respectfully submitted,

—J. M. Bell
—H. T. Fredeen
—P. Robinson
—G. C. Ashton, *Chairman*